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HALLEY'S COMET. SUGGESTIONS FOR ITS OBSERVATION.

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FOR POPULAR ASTRONOMY.

At nearly all of its previous returns this comet has been accompanied throughout its visibility by a fine tail, but at its last visit a most unusual event occurred,—the tail disappeared at perihelion, and a new one was formed later, after the comet had reached the distance of the planet Mars. The two tails were quite unlike in appearance and formation. The first took its origin directly from the nucleus, while the second was simply an elongation of the head, which was at that time greatly extended.

As it is likely that we shall soon be able to observe the formation of the tail ourselves, Herschel's description of the phenomenon as it occurred in 1835 may be of interest, and perhaps cannot be presented better than in his own words*. "On the 2d of October (the very day of the first observed commencement of the tail) the nucleus, which had been faint and small, was observed suddenly to have become much brighter, and to be in the act of throwing out a jet or stream of light from its anterior part, or that turned *towards* the Sun. This ejection after ceasing awhile was resumed, and with much greater apparent violence, on the 8th, and continued, with occasional intermittences, so long as the tail itself continued visible. Both the form of this luminous ejection, and the direction in which it issued from the nucleus, meanwhile underwent singular and capricious alterations, the different phases succeeding each other with such rapidity that on no two successive nights were the appearances alike. At one time the emitted jet was single, and confined within narrow limits of divergence from the nucleus. At others it presented a fan-shaped or swallow-tailed form, analogous to that of a gas flame issuing from a flattened orifice; while at others again two, three, or even more jets were started forth in different directions."

* Outlines of Astronomy 1858, 381.

This phenomenon of the variability of the jets is most unusual, and has a bearing on the question of the rotation of the nucleus about its axis. If visible this year, it should be observed by astronomers with the utmost care, both as to the angular position and the shape of the jets. Bessel* considered the vibration, as he described it, to have a period of 110 hours. This vibration was noted by Hooke when the comet was visible in 1682. The bright material issuing from the jets as it receded from the nucleus was gradually bent backwards, in the opposite direction to the Sun, and drifted away to form the tail.

According to Cowell and Crommelin the comet will transit the Sun May $18^d\ 14^h$. It can therefore be observed to the best advantage in the longitude of Japan and eastern Australia. We must not think of the phenomena however as analogous to the transit of a planet, because owing to the size and proximity of the comet to the Earth, its head, if visible, would probably appear larger than the Sun itself. It is very unlikely that it will be visible however. The great comet of 1882 although so brilliant as to be conspicuous to the naked eye even when close to the Sun, and watched with the telescope until the external contact actually took place, completely disappeared when projected upon the Sun's disk,—indeed the observers thought it had gone behind the Sun.

A comet in transit, however, would appear dark and not bright, so that the comparative darkness of Halley's comet would be in its favor. The heads of comets have frequently been observed to transit faint stars, and in nearly every instance the light of the star has remained unaltered. This was the case with Halley's comet, which transitted two stars in September, 1835. The first of these, observed by Struve at Dorpat, was an all but central occultation, the other by Glaisher at Cambridge, England, was apparently exactly so†. We cannot expect therefore that the light of the Sun will be appreciably dimmed upon this occasion.

The head of a comet, as we now know, consists of a swarm of meteors and a small amount of extremely rarefied gas. The gas certainly cannot be detected by its absorption, unless by means of the spectroscope. This should however be tried. From the stellar transits just cited we conclude that the meteors must be so far apart from one another that the clear sky can

* *Astro. Nach.* 300.

† Clerke's History of Astronomy 1902, p. 106.

be seen between them, even at the apparent center of the head. Individual meteors would obstruct the light of any star for such a brief interval of time that the obscuration could hardly be detected. In the case of the Sun, however, the result would be different, and the comet comes so near us on this occasion that it furnishes an exceptionally favorable opportunity to secure a determination of the maximum limit to the size of the meteors composing its head.

In the Harvard Annals **32**, 147 it was shown that it is possible under favorable circumstances to detect a black spot 0″.1 in diameter against the background of an illuminated disk with a fifteen-inch telescope. At a distance of 14,300,000 miles we should therefore be able to detect any opaque object as much as seventy miles in diameter. We should hardly expect to find any object as large as this within the comet's head, but it would certainly be a matter of the greatest interest to prove that no such body existed. Unfortunately there are but few large refractors well situated for this observation. The transit will occur about one hour before sunset in California. The writer believes there are no large refractors in Australia or Japan. Indeed, the only large instruments in the world really suitably located for this observation are one in Manila, and one near Shanghai.

Those of us who are situated on the other side of the world may see the tail traverse our skies on May 18 at 9^h in the evening, eastern standard time. This will depend however on whether the tail at this time reaches a length of 14,300,000 miles. If the tail is slightly curved, we shall cross the axis rather later in the night. The relative speed of the Earth and tail is about 43 miles per second, or 150,000 miles per hour, so that the duration of the transit may be several hours in length. The longitude of the tail at this time will be 235°, and its end will therefore be seen near the bright star Antares. If well observed, we should be able to determine whether it is hollow or solid, elliptical or circular in cross section, or what is perhaps more likely, of irregular structure. No meteors are expected at this time, since the tail consists exclusively of electrified widely separated molecules of gas, and possibly a little cosmical dust. What meteors are seen are likely to be found about May 6, when we are nearest to the orbit of the comet.

During the last century we passed through the tails of two comets, 1819 II and 1861 II. Not only no harm occurred, but the astronomers did not even find it out, until after it was all

over. The the case of the second comet, on the date in question, June 30, 1861, Hind noted a peculiar phosphorescence or illumination of the sky, and Mr. Lowe said the sky had a yellow auroral glare-like look, although the Sun was above the horizon. This was recorded in the day book of the parish church at the time, before it was known that the Earth was then passing through the tail of a comet. An unusual darkness was noted, and the comet itself had a much more hazy appearance than on subsequent evenings. Chamber's Handbook of Astronomy 1889 1, 462. These phenomena should be looked for, although it is perhaps doubtful if they had any real connection with the comet.

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CURIOUS LUNAR THEORIES OF AN ANCIENT SCIENTIST.

HARLOW SHAPLEY

For Popular Astronomy.

In Lucretius, the Latin representative and exponent of the philosophical school of Epicurus, the world has its most extraordinary poet-scientist. His *De Rerum Natura* ranks as the finest didactic poem of literature, and should be valued as the greatest scientific achievement of the Romans. Astronomy, however, has not benefited especially from the speculations of Lucretius. Enthusiasm and respect for the Epicurean doctrines led him to follow certain dogmatic principles of his Greek predecessors which made his astronomical work much inferior to his other theoretical considerations in science. The poverty of the age in methods of observation upon the heavenly bodies, and the apathy of the Epicureans toward the experimental investigation of natural laws, brought Lucretius to the belief that mankind would never know anything absolutely definite concerning celestial phenomena. It seemed presumptuous to him to maintain that any one special theory of them, no matter how plausible, could be held as the only explanation.

The particular dogma of the Epicureans that clouded their science, and above all injured the astronomy of Lucretius, was that the senses alone can prove the validity of a natural law. Any hypothesis confirmed by the senses is true. And further, theories to which the test of sense cannot be applied and which are not contradicted by it are equally entitled to recognition. The Epicurean theory that lightning was pent-up starlight sud-

denly breaking through the clouds could not be disproved, and therefore was considered as valid an explanation as the prevalent idea that the crashing together of clouds was somehow responsible for the phenomenon.

When dealing with the subjects of evolution and physics, Lucretius shows clear reasoning power and arrives at conclusions far advanced for his times. His results in these branches of science, where the theories could more easily be brought to the final test of the senses, are commensurate with his ability. In discussing a celestial phenomenon, however, he usually gives the true explanation, or the one then generally accepted, together with several other more or less ingenious theories whose only foundation is that they satisfy appearances and cannot be proved to be wrong.

In the presentation of his curious lunar theories Lucretius in general endeavors to justify them by citing familiar terrestrial phenomena which parallel the appearances in the sky. The motions of clouds due to contrary winds suggested to him the relative motions of the heavenly bodies. The Moon, being closer to the Earth than the Sun and the stars, moves in a denser medium and continually falls behind in the daily whirl of the sky[1]. The Sun is retarded less, losing but one revolution a year. Or it may be that the sky is fixed with respect to the Earth and that the heavenly bodies are borne on in their daily courses by various streams of air. Seventeen centuries after Lucretius the theory of a stream or vortex in which the planets float was used by Kepler to account for their different periods[2]. Lucretius suggests other explanations of the irregularities of the motions of celestial bodies, but concludes "that to settle absolutely which of them it is, is by no means the duty of the man who advances step by step[3]." The regular journey of the Moon and the Sun from northern constellations to the burning southern signs is attributed also to the streams of air; and in like manner he would account for the wanderings of the planets.

Among his four different theories of the phases of the Moon Lucretius includes the correct explanation and gives it prece-

(1) *De Rerum Natura*, V, 625. Lucretius attributes this theory to Democritus (350 B. C.). Leucippus, Democritus, and Epicurus are earlier propounders of the science of Lucretius; but their scientific works have all been lost except some letters and fragments of Epicurus.

(2) *De Stella Martis*, cap. lvii.

(3) V 533. Translation by Munro. The astronomical doctrines are nearly all in the fifth book of the poem.

dence. The other proposed interpretations suppose that the Moon shines with its own light. There may be another body travelling in company with the Moon which obstructs the light in all sorts of ways, causing a month-long eclipse, and yet is never seen for it neither emits light nor reflects it. The phenomena of phases can as well be explained by considering the Moon a sphere with but one half of it emitting light[1]. At one time in its course it turns the shining half full on the Earth and later turns it all away. A rotation with respect to the Earth with a period of a month would properly supply the progressive degrees of brightness. And finally, the poet argues, since so many things with which we are acquainted repeat themselves at regular times, such as the falling of frosts, the blooming of flowers in the spring, and the ripening of fruits, it would not be easy to disprove that a new moon is born at a fixed time each day with a regular succession of phases, and at a fixed time is destroyed again. Why should not the Sun, too, be renewed each day by the streaming together at an accustomed time of fires in the east, which form a fiery globe of light that travels the sky and at the end of day, wearied and faded from the long journey, is dissipated into the night? The accumulation and the dispersion of these streaming heats would account for the dawn and the twilight.[2]

Lucretius again makes use of hypothetical dark bodies in space when accounting for lunar and solar eclipses. Why should the Moon be capable of cutting off the Sun's rays from the Earth and it be thought that a lightless body gliding through space could not do the same? The fact that an object of sufficient size to eclipse the Sun or the Moon, though emitting no radiation of its own, should be visible by reflected light, receives no consideration from him. He probably connects with this explanation one of his theories of the Moon that do not involve the reflection of the light of the Sun. Lucretius knew that the absence of celestial dark objects could not be proved, and modern astronomy has found that they do exist. The dark body other than the Earth that can cause the lunar eclipse may be moving in space in company with the Moon, or possibly near the Sun's orbit, throwing its shadow past the Earth to

(1) This is the theory of a self-luminous moon advanced by the Babylonian scientists.

(2) Lucretius had heard that the collection of fires in the east at day-break actually had been observed from the tops of the Ida Mountains in Asia Minor. V 663.

the lunar surface. If the Moon be considered to emit its own light, however, Lucretius explains that the eclipse may simply result because the medium through which the Moon glides is disastrous to its brightness in certain parts of the course. Likewise, the solar eclipse may result from the fires being quenched for a time, to recover full brilliancy again after the fatal spots in the sky have been passed. Perhaps, something of the behavior of flames under different conditions of the surrounding gas was known to Lucretius and suggested to him this grotesque idea of eclipses.

To explain the reason we receive so much heat from the Sun which appears so small, Lucretius suggests that there may well be invisible rays[1] emitted in the vicinity of the visible orb of the Sun, and that the light we see is no index to the entire radiation. Some of the Epicurean scientific beliefs which coincide with modern theories were apparently accidental. The purpose of Lucretius' poem suggests the attitude modern science should take toward the work. *De Rerum Natura* was written in the first half of the first century before Christ at a time when the Romans still saw in the unusual incidents of everyday life and in the workings of nature the intervention of supernatural power—the wishes and whims of a multitude of specialized gods. Lucretius was an enemy of paganism and a fierce opponent of the silly superstitions of his countrymen. To him the world could not be the work of divine power; it was the consequence of obedience to natural laws of indestructible matter and limitless void. The explanation of these physical laws and their application to all natural phenomena constitute his "bold attempt to abolish the gods and deal a deathblow to superstition."[2]

Granting that some of the instances wherein Lucretius anticipates modern theories are chance, still the priority of many of his principles deserves recognition. The first two books of *De Rerum Natura* treat of the atomic theory of matter and

(1) ——*multum caecis fervoribus ignem.* Lucretius advances this theory in defending the prime fallacy of the Epicurean science—the error that has been chiefly responsible for discrediting Lucretian astronomy. The Roman follows Epicurus in saying that the Sun and Moon are about the size they appear to be, arguing, that as long as a terrestrial fire can be seen at all, it appears to be the same in size regardless of distance. Lucretius finds it necessary to show how a small body can emit much heat, and the possible existence of invisible rays occurs to him.

(2) Tyndall: *Atomic Theory of Lucretius*, Living Age, vol. 127, p. 387.

of kinetic energy in such a way that only slight changes in terminology would be necessary to have in the lines of a master poet a fairly good modern treatise on the subject. The explanation of earthquakes is the same as a modern theory. Meteorites are described as the unused material of the universe. Newton's corpuscular theory of light was preceded fifteen hundred years by the analogous Lucretian theory of sight.[1] The Roman scientist said that we see because all objects are throwing off characteristic minute particles which strike the eye. For the phenomenon of sound he entertained a similar theory.[2] Galileo demonstrated at the tower of Pisa the falsity of the Aristotlean doctrine that heavy objects fall with greater velocity in space than lighter ones. Lucretius states that bodies falling in water or air are accelerated *pro ponderibus*, for these elements can not retard everything equally and hence give way to the heavier body; but in empty space there is no resistance to anything in any direction at any time, and bodies, though of unequal weight, fall with equal velocity in the unresisting void.[3]

When dealing with terrestrial sciences, Lucretius has single, steadfast opinions which are always remarkable for clearness and simplicity and are often ingenious and stable. That he adds little to celestial knowledge seems to be the fault of his philosophical creed. His aim was to exterminate superstition rather than to elevate science, and with this purpose in view his interpretations of the heavens were adequate. His great master, Epicurus, wrote "that the knowledge of heavenly phenomena, and of every other science, has no other aim but freedom from anxiety, and that calmness which is derived from a firm belief."[4]

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(1) IV 42, et seq.; rectilinear propagation, IV 609.
(2) IV 524–614.
(3) II 229–235.
(4) A letter from Epicurus to Pythocles, Diog. Laërt. bk. x.

THE ORIGIN OF THE SO-CALLED CRATERS ON THE MOON BY THE IMPACT OF SATELLITES, AND THE RELATIONS OF THESE SATELLITE INDENTATIONS TO THE OBLIQUITIES OF THE PLANETS.*

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In a paper published in the *Astronomische Nachrichten*, No. 4367, November, 1909, the writer has treated of the problem of the obliquities of the planets, from the point of view of the capture theory, and has shown that Jupiter's small obliquity has been produced by the capture and absorption by that giant planet of vast quantities of satellites moving about the Sun in planes nearly coinciding with the plane of the planet's orbit. It is shown by calculation that if the mass of Saturn were increased by this process of capture till it became equal to that of Jupiter, the obliquity of Saturn would become as small as that of Jupiter; whence it is inferred that Jupiter's obliquity was once large and afterwards gradually destroyed by the growth of his mass from the capture of satellites moving near the plane of his orbit. This theory of the planetary obliquities is applied to the other planets of the solar system, and the facts are shown to be in good agreement with the theory.

The origin of the lunar craters has long been a debated question in astronomy, but the traditional opinion dating from the time of Galileo is that they are volcanic; and this view is still held by leading investigators, such as Puiseux, of the Paris Observatory, and Professor Ebert, of Munich. The theory that the lunar craters are volcanic seems to have originated with Hooke, 1667, and was generally held till the time of Humboldt. About the middle of the nineteenth century, however, several investigators, but especially Humboldt himself, and Schmidt, of Athens, became doubtful of the volcanic origin of these circular mountains, mainly because the inner parts of the craters were found to be depressions, with the central peaks below the average level of the lunar surface. A tentative theory that the craters might be due to impact was outlined by Proctor in 1873, mentioned by Newcomb as a curiosity in 1878, and more fully

* Presented to the Astronomical Society of the Pacific, November 27, 1909.

worked out by the geologist G. K. Gilbert, in 1892; but it has never been accepted either by geologists or astronomers.

After a careful examination of all the evidence, I am satisfied that the impact theory is correct, and that the current volcanic theory is not well founded. It happens that the impact theory brings the phenomena of the lunar surface into harmony with the capture theory of satellites and of obliquities of the planets; and it will therefore contribute to our understanding of the phenomena of the solar system. If Jupiter's small obliquity has been produced by the capture and absorption of satellites, the evidence of such collisions, preserved by the indentations in the Moon's face, becomes an important chain in the reasoning for establishing the processes involved in the formation of the planets and satellites. The present discussion is restricted to a brief summary, but the reader who is interested in the subject should be referred to a paper on the cause of the variability of satellites recently communicated by the writer to the *Astronomische Nachrichten*, and to Gilbert's important paper of 1892 (Bulletin of the Philosophical Society of Washington, vol. xii).

In connection with the formation of these craters, Captain A. W. Dodd, U. S. Navy, has made several valuable suggestions resulting from his large experience in various kinds of target practice. He tells me that when the resisting surface is not too hard, experiments with projectiles indicate that the crater will have about three times the diameter of the impinging shell. Accordingly for the lunar surface, with typical craters about sixty miles across, the impinging satellites probably had a diameter of some twenty miles, about like the planet Eros, or the smaller asteroids.

If we wish to calculate the temperature of the falling mass after collision, it is easy to approximate it by the formula for the mechanical equivalent of heat,

$$Q = \tfrac{1}{2}mv^2 = \frac{mv^2}{2 \times 9.81 \times 425} = \frac{mv^2}{8339} \text{ calories.}$$

We find that for a mass of a kilogram, moving with the parabolic velocity of the lunar surface, 2.27 kilometers per second, the result will be

$$\frac{[2370]^2}{8339} = 637 \text{ calories.}$$

If the specific heat of a stony satellite be approximately 0.2, as in the case of terrestrial stone, the effect of the total heat of collision would be to raise it to a temperature of 3365 degrees

Centigrade. But some heat is transferred to the Moon's surface and a considerable part of the energy is expended in sinking a crater and throwing up a wall about it. Notwithstanding this division of the energy it is clear that many of the satellites colliding with the Moon would be more or less melted and and vaporized. As our Moon has no atmosphere, the dust arising from such a conflagration would rapidly fall as metallic and lithic rain, and tend to cover up the ancient craters. The condition of things thus predicted from mechanical theory is strikingly verified by observation of the lunar surface.

It is found that the impact theory explains the following facts:

(1) Both large and small craters, and their superposition over one another, some being older and others newer, as the case may be.

(2) The frequent occurrence of small craters on the rims of large ones, where they would scarcely arise from eruptive causes.

(3) The existence of craters in perfectly smooth plains, as well as in rough and broken regions; and the unequal density of the craters in different parts of the lunar surface. Terrestrial volcanoes generally follow the mountain ranges along the seacoasts. On the Moon the craters are scattered indiscriminately, except that they are rare in maria, for reasons which will hereafter appear.

(4) The greater steepness of the inner walls, and the great diameters of the larger craters, which could not well be explained by volcanic forces. If it be thought that more larger craters ought to be elliptical than are observed, it may be recalled that, even if the first contact with the Moon produced such an outline, the impact of a large satellite would generate enough heat and underlying flow to force out the walls about symmetrically all around, and the final figure would be circular like the globular figure of the satellite. Thus craters which are, say ten times as wide as they are deep, ought to be almost circular; while smaller craters would be more irregular and elliptical, as found by observation. This is because the forcing out of the material beneath small craters is less effective than in the case of large craters, and they retain more nearly their original shape of first contact.

(5) The very flat-bottomed craters, noticed in such regions as Mare Nubium, are due to the filling up of deeper and more irregular craters with cosmical dust, or by melted material which has assumed a level surface. This has at length become so deep as to leave only the walls visible about a level central area, while the central peaks have been nearly or entirely covered up.

(6) In many cases the lunar photographs show that even the walls are practically covered up; for they can now be traced with difficulty, and merely as a faint outline. The walls are covered up, especially in the so-called maria. So far as one can see, two and only two, explanations of these so-called "ghost" craters are possible: (1) The deposit of cosmical dust from the heavens, and from the conflagrations arising in the impact of satellites; (2) The partial melting down of the walls by the conflagrations, which produced the maria, so that only an outline of the original crater walls can be traced. The fact that the "ghost" craters occur chiefly in the level maria supports the conflagration and melting hypothesis, and this certainly is one of the leading causes. But since the earlier craters away from the maria also show the effects of age, as if tending to become obliterated by falling dust, this latter cause also is at work. Moreover, the two causes necessarily are related. Together they explain the ageing of the craters in the rough regions far from the maria, as well as the buried or "ghost" craters in the maria themselves.

(7) This shows that many craters have not only been obscured and partly blotted out by the falling dust, but also that a countless number of these objects have been permanently buried by the process of deposit and conflagration. The so-called seas are areas once made level by melting, in which few recent craters have been formed. The seas of the Moon appear to be singularly level, and this can only point to terrible impacts at some time in the past, by which these whole areas were so fused that pretty much all inequalities of level disappeared. They have since been covered with a layer of cosmic dust, but have suffered relatively few large indentations. They generally appear dark, because the surface is nearly level, and the Sun's light when reflected is but little scattered and seldom so directed that the beam from any considerable part of the surface passed near the eye of the observer.

(8) If this view be correct, it also indicates that the whole Moon was formed by accretion, and that the surface never did experience true eruptive phenomena, such as we observe on the Earth.

(9) The interior of the lunar craters is generally below the level of the surrounding normal surface, and this cannot well be explained except by impact. Volcanic eruptions could not well produce depressions of the crater basins.

"The bottoms of many of the craters are very deeply depressed

below the general surface of the Moon, the internal depth being often twice or three times the external height."—Herschel, "Outlines of Astronomy," § 430.

This remark of Sir John Herschel's shows that decided depression of the basins is common to all craters, both those with rims and those without. It is almost impossible for volcanic forces to produce such a result. One or two Hawaiian volcanoes are the only depressed craters on the Earth, and they are recognized to be exceptions to the general rule of elevation characteristic of our planet.

(10) It is evident that the craters have not been produced by the removal of material from the center and the piling of it up to make the surrounding walls; for in probably three-fourths of the cases, as Professor H. Ebert has shown, it is easily proved by calculation that the volume of the excavation exceeds the volume of the material contained in the wall. This remarkable volume relationship would be explained if the matter beneath the crater were compressed by the force of impact, and only a part of it and of the falling satellites forced out to form the surrounding walls.

(11) The shorter streaks radiating from such centers as Copernicus and Aristarchus are easily explained. It is sufficient to suppose that the collision was so forceful that matter was scattered far out in all directions, and perhaps heated to fusion in the process; yet, as the Moon has no oxygen, it did not burn and blacken as meteoric stones do in falling on the Earth, but simply took on a fused and glassy aspect, which, by reflection, gives the brightness of the shorter streaks radiating from Tycho and its associates. This explanation was given by Mr. Wűrdemann, of Washington, D. C., many years ago, in a letter to Dr. B. A. Gould, but it seems to be but little known to astronomers.

(12) The long rays from craters such as Tycho are similar optical effects of glassy material falling on walls of craters lying nearly in a straight line, and radiating from this center. This is shown by the photographs. Any crater which had matter ejected from it radially, in the process of formation, will have a system of rays, due to the effect of the sunlight on the higher elements of the surface traversed by the rays running from the crater as a center.

(13) As the Moon's force of gravity is feeble, the vapor and metallic and lithic rain due to impact might be carried hundreds of miles, and these streaks due to material falling on corrugations and ridges might extend out from the craters for a con-

siderable distance, and sometimes appear to be prolonged by coincidence with other crater walls or ridges.

(14) The craters which are simple depressions without sensible walls are to be explained by the comparative looseness of the material of the Moon's surface layers,—which allows the mass to yield downward without throwing up much of a wall about the depression produced.

(15) The clefts are paths out by glancing satellites, which thus leave a straight or curved line, according to the nature of the surface and the resistance and rebound. Photographs confirm this origin of the clefts, and show that they are not cracks but actual cuts, sometimes more than a hundred miles in length.

(16) Rills are cracks or offsets along walls of craters which often are more or less hidden by later deposits. They pursue in some cases an irregular course, and often may be due to settlement of loose material, as in landslides on the Earth.

(17) Changes in the aspects of a crater due to caving in, settlement, etc., are always possible; but to be entirely certain that the change is real, the illumination has to be exactly the same as the two epochs, which is seldom possible. If the suspected changes are real, photography will eventually establish this fact.

(18) The covering up of ancient cities on the Earth is due to deposits of waste, rubbish and dust traceable to meteorological causes connected with the atmosphere, such as sand borne by the wind from the desert, etc. On the Moon, however, there is no atmosphere sufficiently dense to carry dust, and it must therefore be scattered by impacts and by direct descent from celestial space. The fact that the older craters are visibly covered up, is a tangible proof of the part played by cosmical dust in the course of ages.

(19) The different degrees of obliteration shown by the various lunar craters is an impressive witness to the progressive falling of cosmical dust, in a celestial world devoid of rain or other meteorological disturbance of any kind.

(20) At zero degrees Centigrade the maximum molecular velocities of the atmospheric gases are found by Dr. Johnstone Stoney to be as follows: oxygen, 18 miles; nitrogen, 20; water vapor, 2.5; helium, 5.2; hydrogen, 7.4. These values usually decrease with the fall of temperature, but the modification thus arising is not very considerable for small changes.

(21) Now, at the surface of the Moon, the parabolic velocity is 1.5 miles (2.37 kilometers, cf. *A. N.* 3992, p. 136) and there-

fore none of these atmospheric gases can be retained. For, although we do not know the Moon's temperature very accurately, it would seem that during the lunar night, it must approach the absolute zero, while during the day it cannot well exceed the boiling point of water. Accordingly, the above values are not sensibly altered by the admissible variations of temperature.

(22) Observations on the refractions of stars occulted by the Moon prove that if any sensible atmosphere exists at the lunar surface, it does not exceed 1/5000th part of the density of the the terrestrial atmosphere. We may therefore conclude that no sensible atmosphere has ever existed upon the Moon, either before or since the capture by the Earth; but that the vapors there arising have congealed into dust or constantly escaped into space.

(23) The cosmical dust that falls upon the Moon therefore encounters no atmospheric resistance, but plunges headlong against the lunar surface. Any vapor due to the force of collision quickly cools and is, if it condenses into solid particles, precipitated as dust, and nowhere amounts to a permanent cloud. If it remains true gas, the molecules gradually escape into space.

(24) If now we compare the lunar photographs with the accompanying imprints made by rain-drops, and by bullets fired into a leaden disk as a target, we shall notice the most remarkable similarity in the two effects. The raindrops, however, are all fluid, and leave only saucer-shaped imprints, and no central peaks; whereas the leaden bullets and stony satellites indenting the lunar surface would necessarily leave central peaks, in accordance with observations. Thus the Moon's surface can be nothing but fragments of rock filled with finer dust; and it is evident that it has never been molten as a whole and has never shown true volcanic activity, as known upon the Earth.

The last conclusion is confirmed from another point of view by an exact calculation given in *A. N.* 4053, p. 345, showing that the total gravitational heat of condensation of the matter of the Moon would raise an equal mass of water through only 408 degrees Centrigrade. It is there pointed out (p. 348) that the development of such a small amount of heat, in the course of long ages, would not at any time give rise to a temperature that would produce fussion of rock. Even when radioactive substances are considered, the conclusion is the same,—namely, that in the slow and almost insensible development of

the Moon by accretion, enough heat to produce general fusion could not have arisen.

Accordingly we may dismiss the old volcanic theory once for all as false and misleading, and may look upon our satellite as a battered planet, which presents to us the most lasting and convincing evidence of the processes of capture and accretion by which the heavenly bodies are formed.

The strength of the present argument regarding the origin of the lunar craters does not rest on one class of phenomena alone, but on several distinct classes of phenomena, which are all harmonized among themselves and brought into accord with the necessary processes of planetary growth. Since worlds form in nebulae, it follows that impacts will necessarily occur; and the Moon's face shows the size of these masses by their imprints, which thus throw an unexpected light upon the state of the solar system in the past.

The variability of the satellites of Jupiter and Saturn, photometrically investigated by Guthnich in *A. N.* 4023 and *A. N.* 4098, indicates that they, too, have maria covering their surfaces, due to collisions, as in the case of the Moon. For, as observed from a distance, the Moon also would be variable, according to the extent of the maria on the side towards the Sun. Lastly, the mathematical argument regarding the capture of the satellites and the Moon is confirmed by Schroeter's observations, 1789-1793, showing that the planet Venus rotates in 23 hours 21 minutes. For if Venus has that period, the Earth never could have rotated faster than at present, and the Moon necessarily would be a captured planet. There is found also to be a theoretical reason why Venus ought to rotate faster than the Earth, so that the capture of the Moon is confirmed both by the observations of Venus and by mathematical theory, and the origin of the lunar craters by impact is a necessary corollary to the capture theory of satellites.

U. Naval Observatory,
Mare Island, California,
November 27, 1909.

PLANET ORBITS II.

THOMAS CURRAN RYAN

FOR POPULAR ASTRONOMY.

Shape and Dimensions.—Continued.

The orbits of all planets contain the same elements, they are results of similar forces and conditions, any one of them may be taken as an example of what all are doing; therefore, and inasmuch as a discrete case best suits my purpose here, I confine myself to a study of the Earth's orbit. The preceding article dealt with the dimensions of the helicoidal orbits as compared with each other; my purpose here is to consider matters relating more especially to their shape. For the sake of clearness the term "relative orbit" will be applied to the closed ellipse which the Earth appears to travel in, and its path as related to outer space will be designated as the "helicoidal orbit."

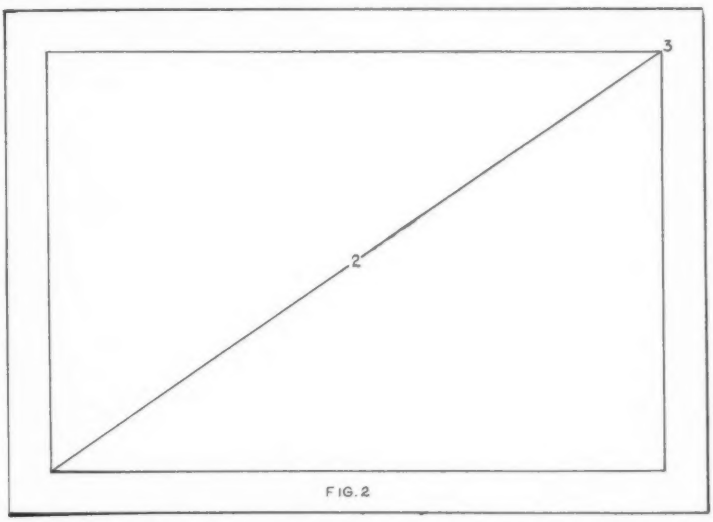

FIG. 2

To begin with, I reproduce Figure 2 of the preceding article and in connection therewith two others derived from it and designated as Figures VI and VII. Figure 2, as shown here, has for its base what in the first article was its left hand side; therefore the Sun's way is from the base upward. Except for this change, it is the same—the longer dimension comparing to

the straightened out circumference of the Earth's relative orbit as the shorter one does to a year's journey of the Sun. The diagonal line represents what the Earth's orbit would be if governed solely by the centrifugal impulse, unaffected by attraction. If the right and left edges of the rectangle are joined to each other, changing it to a cylinder, this diagonal line becomes a spiral. It is to be kept in mind that Figure 2 represents, not the actual orbit, but one which has no eccentricity. It has pertinence to our study, however, as will appear.

The height of Figure VI equals the shortest dimension of Figure 2, or a year's journey of the Sun. Its breadth equals the longest dimension of Figure 2 divided by 3.1416: in other words it stands for the diameter of the Earth's relative orbit.

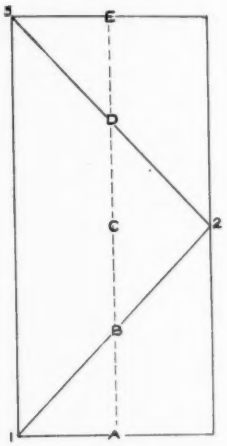

FIG. VI

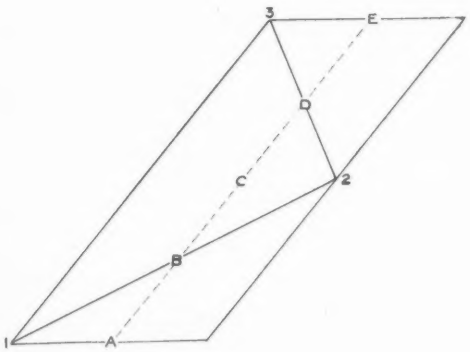

FIG. VII

Thus Figure VI shows the comparative length and diameter of the cylinder that may be formed from Figure 2, and it is to be conceived as a rectangular plane dividing that cylinder longitudinally, into exactly equal sections. Thus conceived, the right and left lines of Figure VI are geometrical elements of the cylinder's surface, separated by the diameter.

All these explanatory remarks apply equally to Figure VII which is a reproduction of Figure VI with the element of obliquity infused into it.

The upper and lower bases of Figures 2, VI, and VII represent the elliptic plane, which necessarily moves along toward the solar apex with the Earth and Sun. The Sun's way is indicated by the dotted lines in Figures VI and VII. From these figures

the diagonal line of Figure 2, representing the Earth's helicoidal orbit straightened out, is missing, and must be *imagined* as a spiral coil around the surface of the cylinder. For convenience we will consider this coil as divided into two curves—*arcs* I propose to call them, though correctly speaking they are not so, since, being spiral in tendency, they do not lie in planes. One of these *quasi* arcs has its convex toward the reader; nothing of this arc, or pertaining to it, appears in Figures VI or VII, except the chord subtending it which is the line 1-B-2 in both figures. The other arc (also absent from the figures) has its convex in the opposite direction and is subtended by the chord 2–D-3. Joined together at 2, these arcs represent a year's journey of the Earth under the conditions assumed in the respective figures.

Figure VII, as before stated, is Figure VI made oblique. Because of this element of obliquity in the helicoidal spiral, and because the relative orbit remains constantly in the ecliptic, an element of eccentricity is brought into the orbit.

As the bases of Figures VI and VII lie in the ecliptic, it is obviously assumed that in the former the Sun's way points to the pole of the ecliptic, while in Figure VII this is not the case. The latter figure is in fact based upon an apex result derived by Ludwig Struve, which he located forty degrees southward from the ecliptic pole, and which, therefore, if true, would mean that the line of the Sun's path inclines away from that pole at an angle of forty degrees.

Since the Earth's relative orbit remains constantly in the ecliptic, the cylinder of space around which the helicoidal or spiral path runs will be more or less oblique if the Sun's goal is not at the ecliptic pole. As the sole difference in form between the two cylinders skeletoned in Figures VI and VII, arises from this element of obliquity in the latter, therefore, inferentially, dynamical or mechanical differences, if any, between two orbits that would severally fit these two cases must, if such differences would exist, be caused by introducing this element of obliquity, since it is the only thing possessed by Figure VII that is not also found in Figure VI,—assuming that all other conditions and all forces in the two cases equal each other.

It is further assumed that the forces and conditions in both cases are those which exist and actually cause the Earth's orbit. But as to one of the conditions, namely distance from the Sun, this latter statement is not clear; so I will add that in Figure

VI the distance is assumed to be what the mean distance actually is, and that figure is drawn upon a scale which makes it 93,000,000 miles. Whether it is in fact a little more or less than this does not concern us here because the actual mean distance, whatever it may be, is what we assume the constant distance to be in Figure VI.

The varying distances and velocities of the Earth in its annual spirals are reducible to a constant average, and their causes result in this constant by opposing and offsetting each other. Those causes are found in two forces which always oppose each other more or less,—namely attraction and the Earth's centrifugal impulse. I say "more or less" because the opposition of those forces is never uniform during any two consecutive moments of the same year. They exert themselves along divergent lines and oppose each other more or less according as those lines diverge more or less.

To illustrate: suppose the line of attraction between two bodies is the one upon which their respective motions are carrying them in opposite directions;—we should then have the maximum of opposition, the stronger force would win, the two bodies would either escape from each other or coalesce. Suppose, again, the reverse of this,—that the respective motions of Earth and Sun were carrying them in the same direction and upon the line of attraction; we should then have negative opposition, or in other words, actual co-operation of the forces—joined in the effort to bring the bodies together. From one of these extremes to the other there would be all shades of opposition between the two forces, including such as would result in more or less eccentric orbits, depending upon the angle that separates the lines upon which the forces happen to be respectively exerted. When from any cause that angle begins to sharpen, the Earth's centrifugal motion offers less resistance to attraction and so the latter force draws the planet nearer to the Sun. When the angle broadens, attraction is resisted more effectively, the centrifugal impulse is relieved and enabled to do its own special work better; and as that work if unimpeded would take the Earth entirely away from the Sun, so it may be, as it sometimes is, exerted strongly enough to increase the distance between them, or so weakly as to lessen it. This is not saying that acceleration and retarding of the Earth's motion will not aid in producing one or the other of these effects; and under the conditions supposed in Figure VII these contributory

causes would exist, but under those assumed in Figure VI they would not.

If we question the conditions assumed in Figures VI and VII as to their respective adaptability or efficiency to furnish the Earth with a relative orbit in the ecliptic, we take it for granted, to begin with, that above and below the cylinders of space respectively outlined by those figures—*i. e.*, occupied by a single year's journey of Sun and Earth—there are innumerable other identical sections of space over which the two bodies have travelled in the past, or will in the future. Let us imagine them reaching simultaneously at the end of some year, the base of cylinder VI. They are now ready to repeat the performance of the previous year. The Sun is at point A, the Earth at point 1. As the length of the chord 1-B-D is exactly the same as the chord 2-D-3, and as the cylinder of space outlined in the figure is perfectly circular, it follows that the Earth's helicoidal path must curve uniformly, that the Earth at every moment of its journey must be at a fixed, unvarying distance from the Sun. In other words eccentricity could not exist in this sort of orbit if the planet remains constantly in the ecliptic plane.

Therefore, since a small amount of eccentricity is found in the Earth's orbit, and as our planet nevertheless is always in the ecliptic, we know that it does not possess the character of orbit outlined in Figure VI, and we must look for conditions that will cause eccentricity while permitting the planet to remain constantly in that plane. In Figure VII we find a condition that will supply one of these demands—eccentricity, perhaps too much of it to permit the Earth to stay in the ecliptic.

As before stated, the speed impulse assumed for Earth and Sun in both figures is that which they now possess; the speed generated would be uniform in Figure VI, but this constant speed is changed in Figure VII to an equivalent average deducible from an aggregate of variations. It should rather be said that this would be the case with any *feasible* eccentric orbit (for we must not assume without a test that Figure VII is feasible). The speed impulse that would keep the Earth at a constant distance in a perfect orbit would in any feasible eccentric orbit keep it at an average distance equivalent to that constant, and would produce an average of speed results equal to the constant of the perfect orbit.

The respective magnitudes of the angles between the line of attraction and the chords of the orbital arcs are, for Figure VI forty-eight degrees and for Figure VII twenty-five degrees at

the beginning of the year's journey. As the larger of these angles would give just the needed amount of conflict between motion and attraction to keep the Earth at an unvarying distance the lesser angle must decrease the distance, and such decrease must continue until the angle broadens sufficiently to turn the scale. I have not space in the present article to explain how this broadening is illustrated by a study of the helicoidal orbit but must confine myself to a statement of what must take place if the Earth did actually possess the character of orbit outlined in Figure VII.

We are to imagine, as in the other case, that the two bodies having completed one annual journey arrive at the base of Figure VII, the Sun at A, the Earth at 1. The planet is required to pursue a path curving toward the reader until the Sun arrives at B, thence curving away from the reader and reaching point 2 when the Sun is at C, thence continuing to curve away and to the left until the Sun reaches D and the planet is at the apex of its second arc, thence toward the reader again until it comes to point 3 and the Sun arrives at E. This is what the planet would be required to do if Figure VII represents its actual orbit. It must describe a curve from point 1 to point 2 while the Sun is moving from A to C. It must do this because when the Sun has arrived at C one half of its year's journey is accomplished, and the Earth is given no handicap in the race but must complete the same half of its year's journey at the same time. Moreover, as the lines of the figure demonstrate, the Earth could not remain in the ecliptic unless it traveled its curve from 1 to 2 while the Sun is moving from A to C.

But the curve upon which this first half of the year's journey is made must not at any point approach nearer to the Sun than the Earth's least distance,—about 91,500,000 miles, nor can the apex of the curve or arc upon which the second half of the year's journey is made be farther from the Sun than the Earth's greatest distance. Could these actual distances be maintained under the conditions imposed by Figure VII? This is an interesting question, but its discussion must be deferred to the next article of this series.

It will perhaps be apprehended by the careful reader, that inasmuch as Figure VII depicts the conditions that must exist provided Ludwig Struve's solar apex result were true, further inquiry as to the adaptability of the Earth's orbit to such conditions becomes incidentally a method of testing all solar apex results derived from star motions. Nevertheless this is not my

purpose. All solar apex results thus far obtained have been derived from studies of the motions of groups of stars. Astronomers have made no attempts of this kind during the last half dozen years, because it has been discovered that the stars *appearing* to possess motion are divisible into two separate streams having apices at widely separated points in the heavens. When the components, directions and velocities of these streams shall have been ascertained with some definiteness, those interested in the search for the Sun's goal can pursue the study more intelligently, by taking heed that each group of stars selected for study shall embrace only members of one stream, and by comparing the conflicting answers given by the different streams. Meanwhile, it is apparent that inquiry into the validity of results obtained by the old methods would be useless; and the fact that I have taken Ludwig Struve's solar apex for illustration means only that I needed something definite as a basis for study, while the intrinsic truth of the selection made is a matter of no importance in the present discussion.

Wausau, Wis. To be continued.

THE DISTRIBUTION OF THE ASTEROIDS.

SAMUEL G. BARTON

FOR POPULAR ASTRONOMY.

The following table shows the distribution of the elements of the 608 asteroids, whose elements are given for the equinox 1910.0 in the Berliner Jahrbuch for 1911. The circumference is divided into 36 divisions of 10° each for M, ω and Ω and the number of asteroids whose elements fall in each division counted. For i and ϕ, each division represents 1°, for μ a division represents 25″ beginning at 275″ [(433) and (434) lie outside the limits of the table]. Thus division 9 represents 90°—100° for M, ω and Ω, 9°—10° for i and ϕ, and 500″—525″ for μ.

THE DISTRIBUTION OF THE ASTEROIDS.

Div.	M	ω	Ω	i	ϕ	μ
0	24	9	8	6	5	2
1	23	16	12	29	16	1
2	18	16	20	46	29	
3	26	16	25	45	45	
4	20	23	21	39	49	
5	12	25	7	43	54	1
6	16	11	17	47	52	
7	18	18	18	41	52	5

Div.	M	ω	Ω	i	ϕ	μ
8	21	15	22	38	53	
9	18	13	20	42	43	1
10	11	22	21	41	53	4
11	12	11	8	32	33	12
12	9	16	23	30	36	4
13	19	12	20	19	26	23
14	14	21	24	16	28	78
15	18	17	18	22	9	33
16	13	17	17	9	5	41
17	10	27	22	5	8	28
18	17	17	24	16	2	23
19	8	22	10	5	5	58
20	12	16	24	6	3	57
21	16	14	18	6	1	45
22	15	11	9	5	1	35
23	13	17	12	6		30
24	13	18	9	2		7
25	15	18	12	6		14
26	6	16	10	2		25
27	18	12	7	1		26
28	19	18	10			15
29	23	19	17	1		7
30	17	17	14			9
31	23	17	15			8
32	15	18	13	1		10
33	38	24	19			4
34	16	16	20	1		
35	22	13	22			

There is no apparent reason why the values of M should not fall at random. The distribution, however, is far less uniform than was expected.

There are 343 nodes less than 180° and but 265 greater.

The μ's are very unevenly distributed. As was pointed out by Kirkwood, there are gaps where the period would be commensurable with that of Jupiter. Jupiter's mean motion is 299″.1. There are for example no asteroids with mean motions between 584″ and 611″ and between 887″ and 903″ corresponding respectively to two and three times Jupiter's motion.

Including all the asteroids with elliptic elements, the most inclined orbit is that of Pallas (2)–35°. Circular elements are given for 1906 WD showing an inclination of 48°. The least inclined orbit is that of (637). The most eccentric orbit is that of Ocllo (475), $\phi = 22°$, $e = 0.38$; the least eccentric is Princetonia (508). The smallest μ *i. e.* the largest major axis is given by Hektor (624). The smallest major axis is, of course, that of Eros (433).

The mean of the elements of the 608 asteroids was also taken with the following results: (for the angles the mean of the degrees was taken and 30′ added as the approximate mean of the other parts, similarly for μ the mean of the whole numbers was taken and 0″.5 added as the mean of the decimal part)

$\omega = 182° 7'$, $\Omega = 169° 2'$, $i = 9° 11'$, $\phi = 8° 25'$, $\mu = 777''.2$, $a = 2.752$

a is obtained from μ by applying Kepler's third law. These results differ some from those given in Young's Manual of Astronomy. The value of a agrees well with Bode's law which gives 2.8.

No particular effort was made to explain the distribution.

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THE CONDITION FOR A MAXIMUM.

ARTHUR B. TURNER

FOR POPULAR ASTRONOMY.

When we have a function of three variables, $\mu = F(x, y, z)$, it is necessary that the term

$$+ \frac{1}{\angle 2}\left(h\frac{\delta}{\delta x} + k\frac{\delta}{\delta y} + l\frac{\delta}{\delta z}\right)^2 F(x, y, z),$$

in the expansion of u by Taylor's Theorem shall be negative in order that u may be a maximum. Dividing by l^2 this term becomes

$$\frac{1}{\angle 2} l^2\left[\left(\frac{h}{l}\right)\frac{\delta}{\delta x} + \left(\frac{k}{l}\right)\frac{\delta}{\delta y} + \frac{\delta}{\delta z}\right]^2 F(x, y, z).$$

Let $\qquad \frac{h}{l} = X, \qquad \frac{k}{l} = Y$

and $A = \frac{\delta^2 F}{\delta x^2}$, $B = \frac{\delta^2 F}{\delta y^2}$, $C = \frac{\delta^2 F}{\delta x\, \delta y}$, $D = \frac{\delta^2 F}{\delta x\, \delta z}$, $E = \frac{\delta^2 F}{\delta y\, \delta z}$, $F = \frac{\delta^2 F}{\delta z^2}$.

Substituting and expanding, we have

$$\tfrac{1}{2}[AX^2 + BY^2 + 2CXY + 2DX + 2EY + F]\, l^2 = \tfrac{1}{2} Z l^2$$

with the condition that Z be negative for a *Maximum.*

The equation

$$AX^2 + BY^2 + 2CXY + 2DX + 2EY + F = Z \qquad (1)$$

represents a surface which must be below the XY plane (since Z is negative), hence two of its traces (those in the XZ, YZ planes), will be parabolas with negative parameters and vertices below the XY plane, and the trace in the XY plane, an

imaginary ellipse. The traces that are parabolas can easily be put in the form,

$$\left[X+\frac{D}{A}\right]^2=\frac{1}{A}\left[Z+\frac{D^2-FA}{A}\right], \text{ and } \left[Y+\frac{E}{B}\right]^2=\frac{1}{B}\left[Z+\frac{E^2-BF}{B}\right].$$

Hence the parameters and the co-ordinates of the vertices are

$$\frac{1}{A}, \quad \frac{1}{B}, \text{ and } \left(-\frac{D}{A}, -\frac{D^2-FA}{A}\right), \quad \left(-\frac{E}{B}, -\frac{E^2-BF}{B}\right).$$

From which it follows that

$$A<0,\ B<0,\ F<0,\ FA>D^2,\ BF>E^2 \tag{2}$$

are the conditions for a *maximum*. In order that equation (1) may represent an ellipse in the XY plane, we have the additional condition that $AB>C^2$. These conditions are combined as follows,

$$AB-C^2>0,\ AF-D^2>0,\ BF-E^2>0,\ 4A^2B^2F^2>4C^2D^2E^2$$

or

$$ABF-C^2F<0,\ ABF-BD^2<0,\ ABF-AE^2<0,\ -2ABF+2CDE<0$$

adding

$$ABF-AE^2-C^2F+2CDE-BD^2<0$$

or

$$\begin{vmatrix} A & C & D \\ C & B & E \\ D & E & F \end{vmatrix}<0, \text{ or } \Delta<0.$$

$\Delta<0$ is easily seen to be the condition that the ellipse in the XY plane shall be imaginary. The equation of the second degree reduces to

$$PX^2+QY^2=\frac{\Delta'}{\Sigma}; \qquad \text{where } P+Q=A+B.$$

From conditions (2) A and B are negative, hence $P+Q$ is negative; and for an ellipse P and Q have the same sign, hence P and Q are both negative. Therefore the conditions for an imaginary ellipse are $\Sigma>0$ and $\Delta'>0$.

But

$$\Delta'=-4\begin{vmatrix} A & C & D \\ C & B & E \\ D & E & F \end{vmatrix} \qquad \therefore \begin{vmatrix} A & C & D \\ C & B & E \\ D & E & F \end{vmatrix}<0.$$

The conditions for a *minimum* can be found in a similar manner.

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ORIGIN OF THE LUNAR TERRESTRIAL SYSTEM BY CAPTURE, WITH FURTHER CONSIDERATIONS ON THE THEORY OF SATELLITES AND ON THE PHYSICAL CAUSE WHICH HAS DETERMINED THE DIRECTIONS OF THE ROTATIONS OF THE PLANETS ABOUT THEIR AXES.* IV

T. J. J. SEE

X. THE TERRESTRIAL SPHEROID ITSELF SHOWS LITTLE IF ANY EVIDENCE OF HAVING HAD MORE RAPID ROTATION IN FORMER TIMES.

The views here expressed by Darwin, who may be considered the highest authority on the subject, accord sufficiently well with those reached by the present writer on the theory that the Moon is captured, to justify the statement that the Earth itself shows little if any evidence of more rapid rotation in former times.

If the supposed greater tidal efficiency of the Moon in past ages is given up, various tidal and physical questions will be left unsettled, and most of the problems of the physics of the Earth will have to be re-examined. The uniformitarian theories in geology will gain some additional importance by changes in fundamental principles which exclude the Moon from a more active part in the past history of the Earth.

Before finally dismissing this important subject it is worth while to remark that some further light on the question of the Earth's rotation in past ages may be gathered from the study of the other planets in space. If we consider attentively the present slow rotations of the other planets, we shall perceive how extremely improbable it is that the Earth once rotated rapidly enough to detach the Moon. The best determined rotation periods of the several planets seem to be the following (cf. *A. N.* 4308):

Mercury	88 days	Jupiter	9.928 hours
Venus	225 days, or 1 day	Saturn	10.641 hours
Earth	24 hours	Uranus	10.1112 hours
Mars	24.62297 hours	Neptune	12.84817 hours

In the case of Venus I have given preference to Schiaparelli's period confirmed by Lowell, though there is perhaps still a little

* From *Astro. Nach.* 4343.

doubt attached to the rotation period of this planet. Working with the spectrograph at Pulkowa, Belopolsky obtained apparently slight spectral displacements corresponding to a period of one day (cf. *A. N.* 3641), but this result was not confirmed by Lowell, who repeated the experiment at Flagstaff under favorable conditions. There are, however, two additional reasons for being very cautious about concluding what the period of Venus is: (1) From the mass of the planet, namely 0.8153 of the Earth's mass (cf. *A. N.* 3992, p. 118), one would expect an original rotation nearly as rapid as that of the Earth, owing to the physical cause which determines rotation, as set forth in the present paper. (2) If a rapid rotation once existed, in a period of about one day, the question arises whether it could have been destroyed by tidal friction. Heretofore we have been inclined to answer this question in the affirmative, but it is not clear that we have been right.It is true that the tidal frictional resistance due to the Sun's action on Venus would be about 5.8 times what it is on the Earth; but Dr. Hecker's recent observations at Potsdam indicate a yielding of the solid Earth under the action of the Moon of only about six inches, according to a statement by Professor Sir G. H. Darwin in a public lecture at Cambridge, May 10, 1909. This corresponds to a solar tide in the solid Earth of only two inches, and this would make the bodily tide in Venus not over twelve inches. For in the paper on the rigidity of the heavenly bodies, *A. N.* 4104, I have shown that the rigidity of Venus must be taken to be but little less than that of the Earth. If then the solid Earth yields to the Sun's attraction to the extent of about two inches, and the solid globe of the planet Venus not over twelve inches, the question arises whether the frictional resistance against the rotation would not be excessively slow, and in fact almost insensible. If the Moon has been captured, as set forth in this paper, it appears that we cannot point with certainty to any sensible retardation of the Earth's rotation, due to the action of the Sun and Moon; nor should we expect such a result from a tidal yielding of the Earth's mass of only about two and six inches, respectively, for these two disturbing bodies. Under the circumstances, it seems necessary to preserve an open mind about the rotation period of Venus.

However, this question may be decided by future events, the period will in no case be appreciably less than a day, and this minimum value is sufficient for our present purposes. What is true of Venus, is even more certainly true of Mercury.

Now the period of $2^h\ 41^m$, or $2^h.7$, found by Darwin for the Earth when rotating as if rigidly connected with the Moon, is only about one-ninth of the present rotation period of the Earth; and even Jupiter, which has the largest mass and shortest period of any of the planets, rotates about 3.7 more slowly than our primitive Earth is supposed to have done. By dividing the primitive Earth's hypothetical period of $2^h.7$ into the period of the other planets, we obtain for the several planets the following minimum numbers, namely: Mercury 9; Venus 9; Mars 9.1; Jupiter 2.7; Saturn 4.0; Uranus 3.7; Neptune 4.8; and may calculate the probability that in seven different cases the observed periods would so much exceed that of the primitive Earth, or that the Earth's original period would have been so much shorter than that of any of the other planets. If the Earth as an ordinary planet of very modest size could really have attained to a rotation in so short a period as $2^h.7$, the chances that seven planets would not all miss in the same direction, and by these amounts, the average being about 6.2, would be about as the continued products of the above numbers, which is 193745. Thus the chances that the Earth could have had such a short period as $2^h.7$ when calculated from the data furnished by the other planets scarcely exceeds 1 in 200000, or the chances are 200000 to 1 that no such short period as $2^h.7$ ever existed. And if the known physical cause of the rotations, as established in this paper, be introduced, the probability becomes practically infinity to one that such a short rotation period as $2^h.7$ never existed; and the probability remains enormous that the Earth never rotated much more rapidly than it does now. So far as one may judge, therefore, by the data furnished by the other planets, we are justified in rejecting once for all the hypothesis that the day was ever appreciably shorter than at present.

Summary and Conclusions.

These several considerations may be briefly summed up as follows:

(1) As all of the other satellites are proved to be captured bodies, the overwhelming presumption is that this is true also of the Moon, and this enormous probability is naturally increased by the demonstrated fact that all the planets likewise have been captured by the Sun, and not one of them detached from that central globe, as was formerly supposed by Laplace and other early writers on Cosmical Evolution.

(2) If we calculate the probability that the otherwise uniform

rule of capturing companions has been broken in the single case of the planet Earth, we shall find the chances against it so overwhelming as to wholly exclude it from consideration.

(3) Thus the companions or satellites could originate in but one of two possible ways; namely, by capture, and by detachment. Let us make the case as favorable as possible to the theory of detachment, and put the probability of the two events each equal to 1/2. Then as we have eight principal planets, 25 satellites (besides our Moon), and over 660 asteroids—all certainly captured—the chances are at least $(2)^{693}$ to unity that the Moon has been captured. This number exceeds a decillion decillion (10^{66}) to the third power, $(10^{66})^3$, and is so enormous that it passes all comprehension.

(4) Even a decillion decillion (10^{66}) is so large that we are compelled to resort to a method employed by Archimedes to illustrate it. Imagine sand so fine that 10000 grains will be contained in the space occupied by a poppy seed, itself about the size of a pin's head; and then conceive a sphere described about our Sun with radius of 200000 astronomical units (α Centauri being at a distance of 275000), entirely filled with this fine sand. The number of grains of sand in this sphere of the fixed stars would be a decillion decillion (10^{66}).

(5) But to correctly understand the actual probability of the origin of the Moon by capture, we must extend the method of Archimedes and conceive all the grains of the sand included within this sphere with radius extending to α Centauri, to be arranged in a continuous straight line as close together as possible (such a line will, of course, extend to infinity), and then imagine a cube erected on this infinite line as a base; and when this infinite cube is entirely filled with the finest sand, all the grains included within it against one is the probability that our Moon also has been captured, and that the lunar terrestrial system forms no exception to the general rule of cosmical evolution by capture prevailing in the development of the solar system.

(6) As this mode of calculation by the theory of probability is entirely rigorous and not merely approximate, it therefore incontestibly follows that our Moon too has been captured and added to our terrestrial system from without, and therefore never has been nearer us than at present, but has come to Earth from heavenly space.

(7) Consequently we conclude that the events traced by Darwin depend on accidental coincidences, and do not represent the true physical history of nature. Accordingly all our previous

conceptions in astronomy, physics of the Earth, and geology as dependent on the Moon's supposed detachment from our planet*, must be wholly abandoned, and all the questions again re-examined, in the light of the new theory, from the ground up. This affords us an impressive illustration of the incompleteness of the physical sciences to-day.

(8) The present distance of the terrestrial Moon in the inner part of the closed Hill surface about the Earth corresponds with the theory that this body has been captured, in which case it could hardly have remained very near the outer portions of this space. When the Moon was first captured, however, its distance can hardly have been less than twice what it is now; so that the distance probably has been greatly reduced in the lapse of ages.

(9) If this view be admissible, it follows that the mean distance has been reduced principally by the secular action of the resisting medium; and the month has been shortened from some eighty days to 27.32166 days, as at present. The original month may have exceeded 100 days, but as Dr. Hill has shown cannot have exceeded 204.896 days.

(10) If the mean distance has been so much reduced, it follows that the eccentricity of the orbit has also been correspondingly diminished. The present eccentricity of 0.05489972 therefore agrees well with the capture-theory. The view that the present eccentricity is a survival of a larger value appears probable in itself; and is in harmony with the tendencies observed in other satellite systems, where the same cause has been at work.

(11) The inclination of the lunar orbit to the ecliptic, 5° 8′ 43″.35, is about what would be expected from the capture theory, and naturally the orbital motion would be direct. For when a body is captured the chances by the theory are much greater that it will move direct rather than retrograde, and we see this theory confirmed by what is observed in the other satellite systems. This follows naturally from the circumstances that a captured satellite has to cross the line of conjunctions before coming under the control of the planet, in order to give a retrograde motion, unless of course such satellite has come in at random and follows no law whatever.

(12) The great preponderance of the Moon's moment of momentum of orbital motion (3.384) over that of the Earth's axial rotation (0.7044) is of itself a suspicious circumstance, and

* The theory that the Moon was thrown off from the Earth seems to date back to Anaxagoras, B. C. 500–428.

difficult to account for, without introducing violent hypotheses. But if the Moon is captured this unusual circumstance presents no difficulty.

(13) Darwin's celebrated diagram does not show how the system of the Earth and Moon came to be started; but only shows what will follow from a given condition of the system. Now if the bodies were started to revolving in a perfect vacuum, they might separate as he supposed, but if the resisting medium is more effective than tidal friction, the bodies will approach one another in spite of the energy curve in the diagram; for this curve rests on dynamical equations which postulate no resistance. When the resisting medium is introduced the energy curve is no longer valid, but the outcome will depend on the relative importance of the two rival forces—tidal friction and the resisting medium, the secular effects of which are exactly opposite. In order to judge which is likely to predominate, it is sufficient to recall the circularity of the orbits of the planets and satellites noticed elsewhere in our system, and directly traceable to this latter cause and no other.

(14) Halley first suspected the existence of a secular acceleration of the Moon's mean motion in 1693. It was confirmed by Dunthorne in 1759, and in the same year Euler advanced the view that all the heavenly bodies were subject to the secular effects of a resisting medium. Notwithstanding Laplace's celebrated discovery in 1787 that the secular decrease in the eccentricity of the Earth's orbit was responsible for most of the observed secular acceleration of the Moon, it continues to be an unsettled question. The correction of Laplace's process of calculation by Adams in 1853, and the verification of the latter's procedure by Delaunay, Plana, Lubbock, Hansen, Cayley, and others, allows gravitational theory to account for only about two thirds of the observed effect indicated by the most ancient observations, 6″.11 according to Delaunay, while the most ancient eclipses of the Sun make the observed secular acceleration about 12″.00. And recently Mr. Cowell has confirmed a secular acceleration of the Moon of at least 9″ by new researches on eclipses, and besides found a sensible secular acceleration of the Sun, which could be accounted for by any hitherto recognized cause. Why not go back to Euler's sagacious suggestion of the resisting medium to explain both of these outstanding anomalies? If the resisting medium has shaped the orbits of the heavenly bodies, it has not yet entirely disappeared but must produce small effects which are sensible to observa-

tions extending over long ages.

(15) And of all the bodies in our system adapted to disclosing the secular effects of this slowly acting cause, the Moon is by far the most sensitive, as was long ago remarked by Euler. It is like a delicately adjusted chronometer, and the slightest disturbance will at length become sensible to observation; The next most sensitive of the heavenly bodies is undoubtedly the Sun (or rather the Earth), because of the accuracy of our modern observations and the considerable period over which they have extended. And here it is that Mr. Cowell of Greenwich has recognized the anomalies which heretofore have been attributed to the secular effects of tidal friction in changing the length of the day.

(16) If the views set forth in this paper be admissible, they will tend to restore our confidence in ancient eclipse observations, and also in the steadiness of the Earth as a time keeper, while they will give a severe shock to those who consider the heavenly spaces devoid of sensible resistance. And while the effects attributed to tidal friction seem to be less important than they have been supposed to be, on account of the present great distance of the Moon, and the indication that it has never been sensibly nearer the Earth, yet the importance of this cause will always be considerable, both in our own system, and in other systems observed in the immensity of space. The change in our point of view of course does not diminish the value of Professor Sir G. H. Darwin's celebrated work on this subject, but simply limits the scope of the results when applied to the systems nearest at hand. Even if inapplicable to the Moon or applicable to but a limited extent, his beautiful analysis will always be the basis of future researches in this extensive subject, which deals with one of the most important physical causes affecting the figures and motions of the heavenly bodies.

U. S. Naval Observatory,
Mare Island, Calif., May 22, 1909.

Addition. In the December (1909) number of POPULAR ASTRONOMY, page 637, line 5 from top, after the words: "four times the present distance of the Moon" insert: The value thus obtained is the maximum value, corresponding to the part of the surface nearest the Sun; of course other parts of the surface are nearer the Earth.

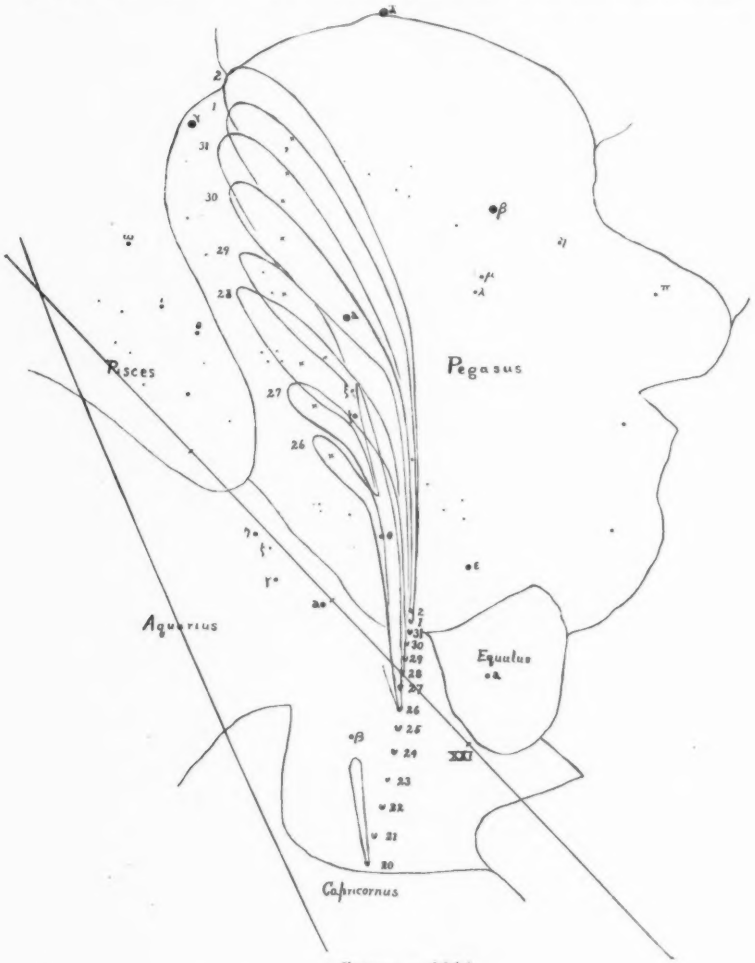
(Conclusion.)

DRAWINGS OF COMET *a* 1910.

A. E. DOUGLASS

For Popular Astronomy.

The accompanying drawings show the extraordinary development of the tail of the comet recently visible in the western sky



Comet *a* 1910

after sunset. The comet was first seen here about a half hour after sunset on January 20th, and has been seen nearly every

night since then. At first its tail was straight and narrow and some 6° or 8° long. After the clouds of the 23rd had cleared away, it showed a slight curvature and rapidly increased in length till on the 26th it was some 24° long. On this date a southern branch was evident, a feature of peculiar interest, for it did not appear to be a separate tail starting from the head, with a stronger curve, but it looked distinctly like a branch from the main tail at a distance of 16° from the head. This character was noticed independently by many persons, even as late as February 1, when the sharpness of the bend at the point of joining the straighter tail was much less apparent. Moreover this branch showed an increased condensation at about its apparent center in the form of a very diffused mass of cometary matter. In the diagram the outline of this branch is given with its date and the position of the brighter center is marked with an X.

As first seen the nucleus appeared about one-eighth of the diameter of Venus, with a brilliant coma pushed well out ahead of it. In the course of ten days the coma disappeared and the whole comet grew fainter as it receded from the Sun, and the tail, while becoming fainter, increased vastly in size until on February 3rd it had the enormous length of 45°. Every estimate of length has been corroborated by several observers. The chief difficulty has been the interference of the zodiacal light in which the fainter tail disappears. The following table gives the rough positions obtained with the eight-inch Harvard telescope loaned to this University. They were made by setting off distances in R. A. and Decl. from Venus :

1910	G. M. T.	R.A.	and	Decl.	Tail length		
Jan 20	13 40	20	52-3	—12	8°	Straight (estimated	
21	13 40		58.4	10	6.5	Measured, (as all below)	
22	13 44	21	03.7	8.0	9.5		
23	Cloudy						
24	13 38	21	13	23 4.5	11	Position of condensation	
25	13 21		18	05 3.1		in Tail :	°
26	13 36		21	56 2.0	24	$22^h\ 32^m$	+ 7.5
27	13 24		26	07 — 0.85	26	22 46	8.8
28	13 38		29	24 + 0.1	32	22 59	10.0
29	13 39		31	23 1.0	33	23 17	12.5
30	13 43		34	05 1.85	37	23 29	14.7
31	13 44		36	39 2.6	39	23 38	16.4
Feb. 1	13 41		39	01 3.2	40	23 43	17.9
2	13 50		40	53 3.76	42	23 46	19.7
3	Partly cloudy				45	23 49	19.9
4	Partly cloudy						
5	Partly cloudy						
6	13 49	21	48	06 + 6.0	45 ±	Too faint.	

University of Arizona, Tucson, Arizona,
February 6, 1910.

THE JULIAN STAR.*

FREDERIC STANLEY DUNN

When Halley's comet was still several leagues away in the depths of the firmament, I had rather an amusing adventure in anticipation of its coming, the rehearsal of which may be both interesting and instructive to my fellows in the classics.

I had been invited to attend an 'at home' by the Latin instructor in our local high school and to address the class in whose honor the occasion had been planned. Happening to note that the date assigned was the eve of the March Ides, the suggestion readily came to my mind to take advantage of the coincidence and discuss the assassination of Caesar. His deification finally became my appointed theme, with the *Iulium Sidus* (Hor. Carm. 1,12.47) as the nucleus of my address. Only an hour or so previous to my coming before the assembled company, I was overjoyed to stumble upon what was to me a most astounding discovery. Armed with it, I expected to take my audience by storm.

In Duruy's History of Rome, Volume 3, Section 2, p. 559, foot-note 2, may be found this comment upon the 'hairy star' that played such an important part in the apotheosis of Caesar: "*The comet which appeared at that time was Halley*'s." Even that early, although it was March of 1904, public interest was becoming alert over the expected reappearance of the great comet in 1910, so that the above statement was, to say the least, decidedly attractive. The time to give my address was almost upon me, and I had not the slightest hesitation in accepting the dictum of Professor Mahaffy, who, as the English editor of Duruy's History, I knew was responsible for the note. My peroration was a magnificent effort, something to this effect: "And so, if we are spared to live until 1910, we shall have the pleasure of looking again upon the blazing emblem that is the soul of our great Julius, metamorphosed to the realm where it surely belongs, a seat above the greatest of Rome's gods."

It was not until almost a year after those March Ides of 1904 that I found, to my horror, that, without the leadership of M. Jules Verne, I had been veritably 'Off on a Comet.' In February of 1905, I again took up the theme in a more elaborate vein, recasting it to present before the Faculty Colloquium of the

* *Classical Weekly*, Jan. 8, 1910.

University of Oregon. Somehow, a doubt had crept into my conscience about that brilliant finale of my former address—perhaps because, in all the popular accounts of the several appearances of the comet and of the historic events with which it was connected, no mention had elsewhere been made of so singular an event as the assassination of Caesar. I therefore began a systematic study from an astronomical standpoint and was shocked to learn how far astray I had been unwittingly led. Unlike Galileo, I am only too anxious to publish my recantation, in the hope that others may avoid digging the same pit for themselves and pulling their followers therein after them. A glance at the table of its reappearances, or, if that is not available, a simple mathematical process, will quickly prove the futility of identifying Halley's comet with the 'Iulium sidus', for the nearest appearance to the date in question was probably in 11 B. C.—thirty-three years after the assassination and the celebration of Octavian's games, when the comet is distinctly said to have appeared.

This curious but unfortunate error should be given publicity, for the popularity and widely accepted erudition of the Duruy's history are quite apt to disseminate a very gross misconception, to which my own experience bears witness.

Eugene, Oregon.

THE APPARENT PATH OF HALLEY'S COMET IN THE SKY.

WILLIAM F. RIGGE

FOR POPULAR ASTRONOMY.

Halley's comet, as we know, moves in a very elongated ellipse. While its farthest excursions carry it beyond the outermost planet of our system, its nearest approach to the Sun is almost half of our distance from that luminary. As the comet is visible to us only when in this latter part of its orbit, this is drawn somewhat in detail in Figure 1.

The four circles in this diagram are the orbits of the four inner planets. The position of the Earth is given for the tenth, twentieth and last days of every month throughout the year. That of Mars is similarly given only from January to September, that of Venus from January to May, and that of Mercury during March, April and May. The name of the month is al-

ways placed between its tenth and twentieth days, so that the position of any of these planets may readily be found for any date whatever.

The large curve is part of the orbit of Halley's comet, on which its position is noted from December 26 of last year until August 13 of the present one. The point *P* is the perihelion, or point of nearest approach to the Sun at a distance of 0.58720 of the Earth's mean distance. This, as we see, brings the comet

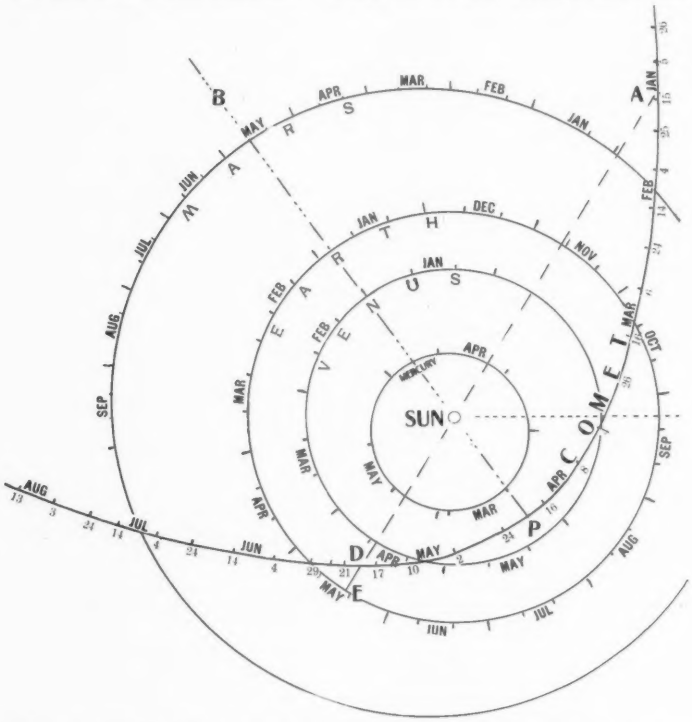


FIGURE 1.—The Orbit of Halley's Comet relatively to the four inner Planets.

well inside the orbit of Venus. The line *PB* running through the perihelion and the Sun and extended into space, is the major axis of the ellipse.

The line *DA* is the line of nodes, or line of intersection of the plane of the comet's orbit with that of the Earth commonly called the ecliptic, the inclination being about eighteen degrees. The comet crossed that line about the middle of January at the point *A*, called the ascending node, because it then passed

to the north of the plane of the ecliptic. On May 18 it will pass through the descending node *D* and again go to the south of the ecliptic, to remain there during the rest of its long period. By a fortunate coincidence the Earth will also be on this line of nodes at the point *E* at the same time, so that the comet will pass directly between us and the Sun and envelop us with its tail. This last event need not cause us any alarm, as it is not likely that any but professional observers will ever notice any thing unusual at the time, if they will be able to notice any thing at all.

As we ourselves are on a travelling observatory, the apparent path of the comet in the sky will partake of its own proper motion along with ours. The result will be a very complicated curve, which required the genius of the greatest astronomers to reduce to such a simple figure as the ellipse. Figure 2 will give us an idea of the comet's apparent path. The diagram is ruled off into squares of five degrees. The large numbers at the bottom, 9, 8, ... 23, 22, are the hours of right ascension, and those on the side, 0, 10, 20, are degrees of declination, the *O* line being the celestial equator. All the stars brighter than the third magnitude are represented in their proper places. The dot-and-dash curve beginning at the right-hand lower corner and marked SUN, is the path of the Sun, upon which its position is indicated for every five days. The paths of the planets Mars, Saturn and Venus during two or three months are also represented. Those of Mercury and the Moon were omitted, because they would have congested the diagram too much.

The full line is the apparent path of Halley's comet, on which its position is marked from October 7 last until the end of next May. We see that about the beginning of October or shortly before, the comet changed its direction, moving westward instead of eastward as before. This is explained by a reference to Figure 1. If we locate the Earth on its orbit during September, we see that the comet's orbit above and beyond December 26 where it was at that time, is practically a straight line as seen from the Earth. The Earth is approaching the comet's orbit from the right, so that by the time it has come to the November part of its own orbit, it has crossed the comet's line of motion and thereby apparently thrown it to the right or westward.

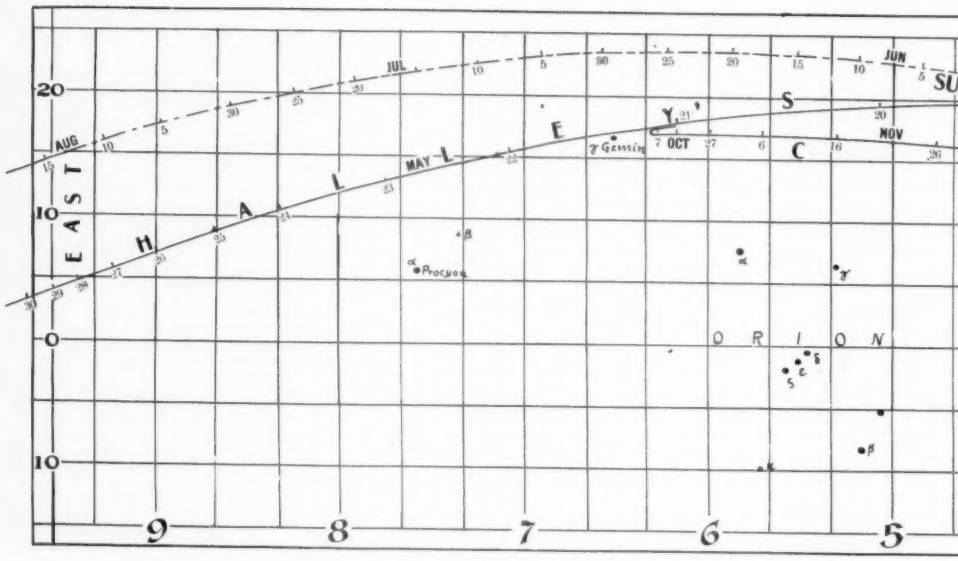
If we place a ruler on corresponding positions of the Earth and the comet during the months of November, December and the following ones, we shall see that the ruler will keep on

swinging to the right, apparently throwing the comet westward, until with a diminished rotation the ruler will come to a halt about April 24, and then begin with increasing rapidity to swing to the left, thus throwing the comet eastward. This explains the second stationary point on Figure 2 on April 24, as also the very rapid apparent motion of the comet about May 20. After this date the eastward speed will decline more and more during many months.

The points *A*, *P*, *D*, are the same on both figures. On Fig. 2 we see that at *A* on January 18 the comet crosses the Sun's path, or the ecliptic, and passes north of it. The Sun is not there at the time. At *D* on May 18 it crosses it again to the southward. At this time the Sun and the comet will be there together, and the comet will appear to cross directly before the face of the Sun, that is, to transit it. This, however, will not be visible in America.

By comparing corresponding dates of the comet and the Sun on Figure 2, where both are given for Greenwich noon, that is, 6 A. M. central time, we can get a very good idea of their relative positions in the sky. When the comet is to the right or west of the Sun on the diagram and in the sky, it rises and sets before the Sun, and is therefore visible only in the morning before sunrise. When it is to the left, it is visible only in the evening after sunset. The duration of this visibility of the comet before sunrise or after sunset may be estimated by the distances apart of these bodies on the diagram. It is given more accurately in the subjoined table, which has been prepared for the latitude of Omaha. A slight correction would seem to be necessary for places in other latitudes in the United States, but as this correction is small and as the comet will be very large and move rapidly, it may be neglected without sensible error.

Comet sets later than the Sun.		Comet sets later than the Sun.	
Feb. 4	$5^h\ 10^m$	May 20	$1^h\ 0^m$
14	4 20	21	2 0
24	3 10	22	2 45
Mar. 6	2 10	23	3 15
16	1 15	24	3 20
Comet rises earlier than the Sun.		25	3 40
April 4	0 50	26	3 50
16	1 30	27	4 0
24	1 55	28	4 5
May 6	2 10	29	3 55
10	2 20	30	3 50
12	2 10		
14	2 00		
15	1 50		
16	1 30		
17	1 5		


AUG
JUL
JUN
MAY
OCT
NOV
HALLEY'S COMET
EAST
20
10
0
10
9
8
7
6
5
γ Gemin
Procyon
ORION

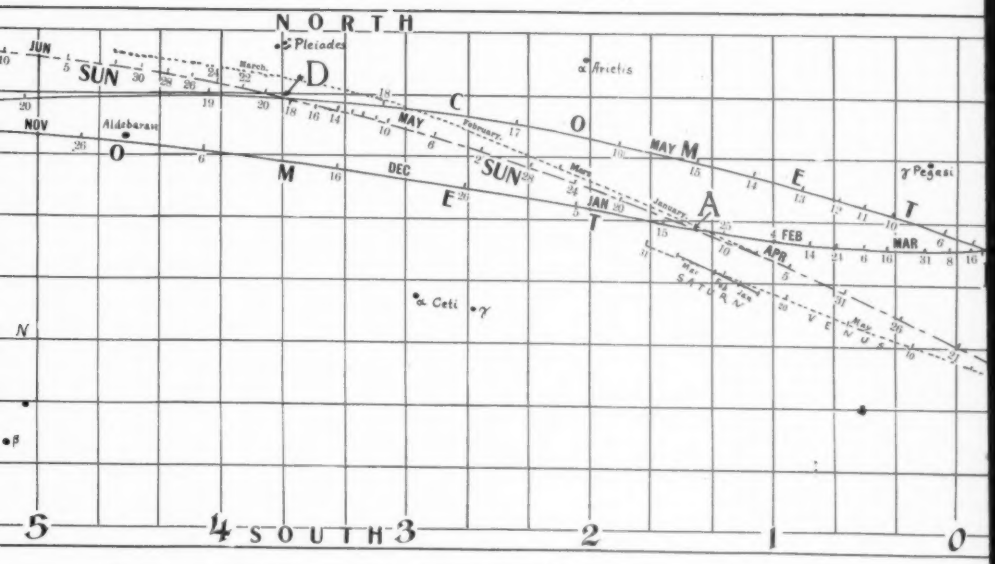


FIG. 2. Apparent Path of Halley's Comet.

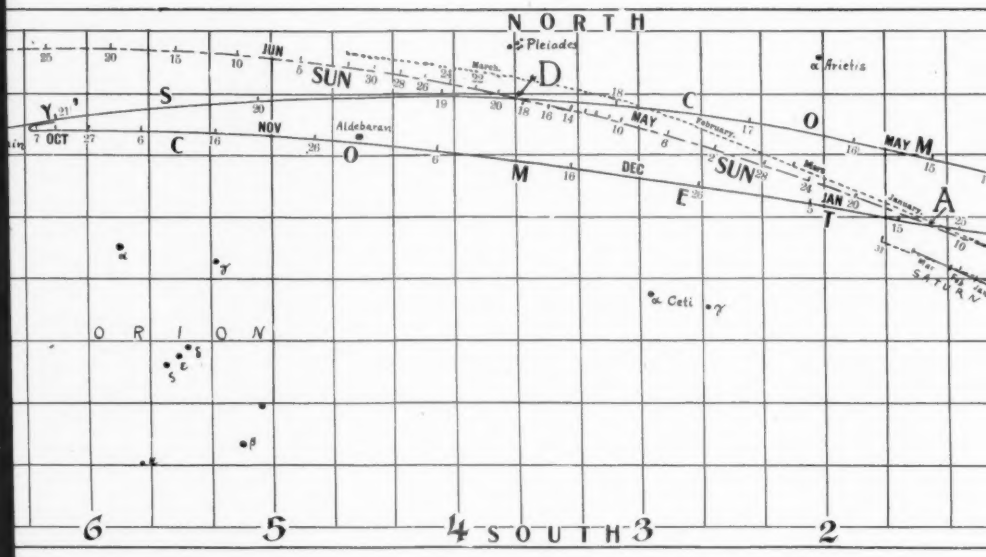
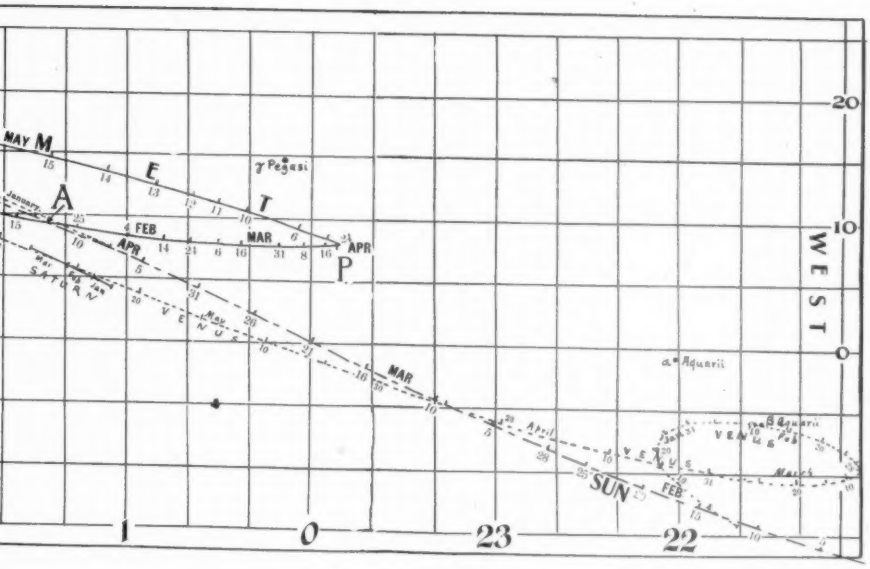


FIG. 2. Apparent Path of Halley's Comet.


MAY
M
E
T
A
P
γ Pegasi
FEB
MAR
APR
JANUARY
SATURN
VENUS
MAR
April
SUN
FEB
α Aquarii
β Aquarii
March
20
10
0
WEST
1
0
23
22

A diligent study of the map in Figure 2 will enable one to locate the comet at any time, either absolutely by its right ascension and declination, or relatively with regard to the Sun, Mars, Saturn, Venus or the stars. It will thus enable one to pick it up with an unmounted telescope before it becomes so conspicuous as not to need this aid, as well as to know its motion in advance. Thus we see that the comet will approach the Sun slowly until March 25. It may possibly be visible to the naked eye before that date, but for a week or more before and after that time it will be too near the Sun to be seen. From March 25 to May 19 the comet will be visible in the morning sky before sunrise, its greatest distance or elongation to the right or west of the Sun occurring about May 8, when it will rise about two hours before the Sun. It will then in ten days move with continually increasing speed toward the Sun until it passes it on May 18, being lost in its rays for a few days before and after that time. It will after that be visible in the evening sky, separating at first very rapidly from the Sun and then more and more slowly until the early part of June, when it will approach the Sun again and gradually disappear from view, as well on account of its increasing distance from the Earth as also on account of its apparent increasing proximity to the Sun. It will be our last view of Halley's comet, as very few, if any, of us will be here after 75 years to greet it at its next return.

Creighton University Observatory,
Omaha, Nebraska.

SPECULUM MAKING.

LEO HOLCOMB

For Popular Astronomy.

There is great pleasure over meditation in trying to conceive of the nature and structure of the universe and in watching the wonders of the sky in their movements from month to month, reading the fascinating books telling of the great work being done in our observatories with that wonderful instrument the telescope. But to such a one reading about these grand sights in the sky that may be seen by any one possessing a moderate sized glass, when he himself cannot have such opportunity—generally by reason of its great cost—such a state of things is exasperating indeed.

Telescopes should be more generally in the hands of amateurs. In 1907 I noticed an article in *Popular Mechanics* which stated that a young farmer boy had made a telescope with which he had found a comet not previously known to the astronomers. Shortly after, I read an article in POPULAR ASTRONOMY by Mr. A. R. J. F. Hassard in which he said he had made a telescope after the same manner as had John Mellish, the young man above mentioned.

It is just such articles as these appearing that attract the attention of the would-be astronomer and give him the idea that may result in an opportunity for which he has been hoping.

Speculum or mirror making is a most fascinating and gratifying pastime and the production of a mirror possessing a true parabolic figure is a work requiring skill, and a work of which one may well be proud. In England this work is carried on quite extensively among the laymen and if one may judge from

their writings and discussions, the pursuit has attracted some unusually brilliant and talented adherents.

It is quite within the range of any one possessing energy and ambition to make with his hands a reflecting mirror of great power and at very slight cost. I am using a mirror of 10¼ inches diameter that I made during some spare evenings of the winter of 1909, and it compares favorably with mirrors made by opticians of reputation. The telescope here shown is the one I am now using, it has a twelve-inch tube which is large enough to accomodate any size of glass up to eleven inches diameter if the mirror is not less than seventy inches of focal length.

I hope to see an interest created in speculum making in this country among laymen, which if not being the "means to an end," will be the means of their seeing some of the beauties in the great dome of heaven that is eternally sweeping past them and will be an instrument in their hands with which they may help solve some of the great problems confronting the science of astronomy.

Decatur, Illinois.

THE SUN.

ALICE BERLINGETT

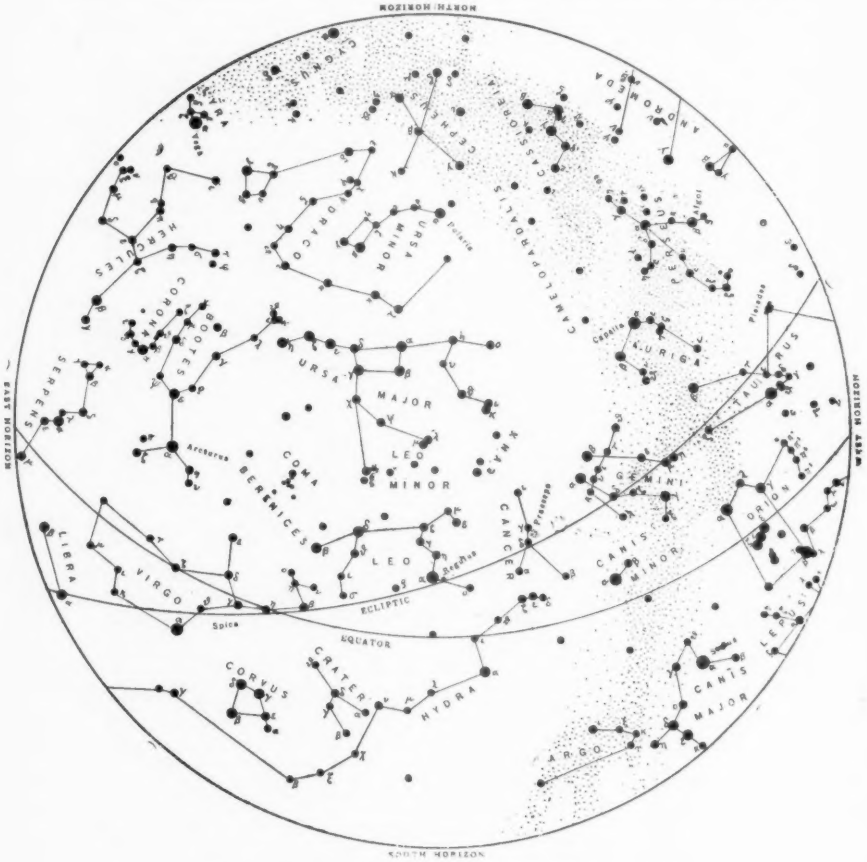
FOR POPULAR ASTRONOMY.

To thee, O glorious Sun, we tribute pay!
What wonder that the Ancients worshipped thee,
And called thee, "Lord of Day!" Could they not see
That death would come to all without thy ray?
Material father of the world thou art!
Through thee the various seasons have their birth,
And they in turn rich gifts bestow on Earth,
Which of their sustenance to man impart.
But science tells us thou, O Sun, must die,
And though our lives depend upon thy light
Yet not of thee is man still asking, "Why,
And wherefore came we here, and whence our flight?"
"Though suns shall die," the soul then makes reply,
"Beyond all worlds there is eternal light!"

PLANET NOTES FOR APRIL, 1910.

Mercury will be at superior conjunction on April 5, and so will be invisible during this first half of the month. It will be at perihelion April 15.

Venus is morning star and will be brilliant in the east a couple of hours before sunrise. She will be at greatest elongation, west from the Sun 46° on April 23.



THE CONSTELLATIONS AT 9:00 P. M., APRIL 1, 1910.

The phase will be crescent until about the 24th, when exactly half the disk will be illuminated.

Mars may be seen toward the west during the early part of the night and will reach its greatest northern declination at the end of the month. The apparent diameter of the disk of Mars is now only about 5″ so that little of detail can be seen upon the planet.

Jupiter has just passed opposition and therefore is in best position for study this month. The four bright satellites are visible in quite a small telescope and the two most prominent belts are always seen so that the amateur astronomer seldom fails to find this planet interesting to look at. Jupiter will be in conjunction with the Moon April 21 at about midnight.

Saturn will be in conjunction with the Sun April 16, and will not be visible during this month.

Uranus will be at quadrature, 90° west from the Sun on April 15, and may be found in the constellation Sagittarius (see chart in POPULAR ASTRONOMY, January, 1910).

Neptune is in Gemini, visible only with the aid of a powerful telescope. It will be at quadrature, 90° east from the Sun, April 6.

Occultations visible at Washington.

Date 1910	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle from N. °	EMERSION. Washington M.T. h m	EMERSION. Angle from N °	Duration. h m
Apr. 12	51 Tauri	5.6	6 40	115	7 32	223	0 52
12	56 Tauri	5.2	7 12	84	8 13	257	1 01
12	67 Tauri	5.4	9 47	28	10 16	317	0 29
16	λ Cancri	5.9	9 31	105	5 57	276	1 26
18	η Leonis	3.6	5 25	146	6 35	261	1 10
18	42 Leonis	6.1	14 57	104	15 49	304	0 52
24	8 Librae	5.4	17 46	146	18 37	249	0 51
24	α^2 Librae	2.9	17 58	155	18 41	240	0 43
25	11 H. Librae	5.4	14 13	130	15 39	280	1 26
26	ρ Ophiuchi	4.7	16 52	128	18 04	255	1 12
30	A Sagittarii	4.9	13 48	144	14 32	213	0 44

Phenomena of Jupiter's Satellites.

Central Standard Time.

1910	h	m			
April 1	10	52	I	Oc.	Dis.
	13	06	I	Ec.	Re.
	13	17	II	Oc.	Dis.
	16	02	II	Ec.	Re.
2	8	07	I	Tr.	In.
	8	11	I	Sh.	In.
	10	21	I	Tr.	Eg.
	10	26	I	Sh.	Eg.
3	7	35	I	Ec.	Re.
	7	39	II	Tr.	In.
	7	48	II	Sh.	In.
	10	18	II	Tr.	Eg.
	10	31	II	Sh.	Eg.
	13	18	III	Tr.	In.
	13	31	III	Sh.	In.
	15	29	III	Tr.	Eg.
	16	04	III	Sh.	Eg.
7	15	25	I	Tr.	In.
	15	37	I	Sh.	In.
8	12	36	I	Oc.	Dis.
	15	00	I	Ec.	Re.
	15	32	II	Oc.	Dis.
April 9	9	52	I	Tr.	In.
	10	05	I	Sh.	In.
	12	05	I	Tr.	Eg.
	12	20	I	Sh.	Eg.
10	7	02	I	Oc.	Dis.
	9	29	I	Ec.	Re.
	9	53	II	Tr.	In.
	10	22	II	Sh.	In.
	12	32	II	Tr.	Eg.
	13	05	II	Sh.	Eg.
12	7	57	II	Ec.	Re.
14	6	11	III	Oc.	Dis.
	9	53	III	Oc.	Re.
15	14	20	I	Oc.	Dis.
16	11	36	I	Tr.	In
	12	00	I	Sh.	In.
	13	50	I	Tr.	Eg.
	14	15	I	Sh.	Eg.
17	8	46	I	Oc.	Dis.
	11	23	I	Ec.	Re.
	12	07	II	Tr.	In.
	12	56	II	Sh.	In.

Phenomena of Jupiter's Satellites.—Continued.

	h	m			
Apr. 17	14	46	II	Tr.	Eg.
	15	38	II	Sh.	Eg.
18	6	28	I	Sh.	In.
	8	16	I	Tr.	Eg.
	8	43	I	Sh.	Eg.
19	6	58	II	Oc.	Dis.
	10	34	II	Ec.	Re.
21	9	29	III	Oc.	Dis.
	13	51	III	Ec.	Re.
23	13	21	I	Tr.	In.
	13	54	I	Sh.	In.
	15	36	I	Tr.	Eg.
	16	09	I	Sh.	Eg.
24	10	30	I	Oc.	Dis.

	h	m			
Apr. 24	13	17	I	Ec.	Re.
	14	23	II	Tr.	In.
25	7	48	I	Tr.	In.
	8	23	I	Sh.	In.
	10	02	I	Tr.	Eg.
	10	38	I	Sh.	Eg.
26	7	45	I	Ec.	Re.
	9	16	II	Oc.	Dis.
	13	10	II	Ec.	Re.
28	7	30	II	Sh.	Eg.
	12	49	III	Oc.	Dis.
	15	13	III	Oc.	Re.
	15	33	III	Ec.	Dis.

Note.—In., denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., Transit of the Satellite; Sh., transit of the shadow.

COMET AND ASTEROID NOTES.

Elements and Ephemeris of Comet Tempel$_2$ (1873 II).—In *A. N* 4386 Mr. E. Maubant of the Paris Observatory gives the following elements and ephemeris of Tempel's second periodic comet which is now due at perihelion, but is on the farther side of the Sun.

Epoch and Osculation 1910 Feb. 21 Paris

$M = 2° 04' 21''.2$
$\pi = 307\ 16\ 41\ .6$
$\Omega = 120\ 37\ 58\ .7$ 1910.0
$i = 12\ 45\ 16\ .7$
$\phi = 33° 54' 20''.9$
$\mu = 685''.881$
$\log a = 0.475839$

Ephemeris for Paris midnight.

1910		α h	m	s	δ °	′	″	log Δ	$1:r^2\Delta^2$
Mar.	1	22	12	39.4	−14	03	28	0.36186	0.105
	5	22	26	28.1	13	10	03	0.36285	0.103
	9	22	40	03.7	12	14	42	0.36405	0.101
	13	22	53	26.0	11	17	46	0.36543	0.099
	17	23	06	34.8	10	19	39	0.36698	0.097
	21	23	19	29.3	9	20	42	0.36868	0.094
	25	23	32	09.8	8	21	15	0.37052	0.092
	29	23	50	44.7	7	21	31	0.37248	0.089
April	2	23	56	49.4	− 6	22	04	0.37454	0.086

Winnecke's Comet.—In *A. N.* 4383 Mr. C. D. Perrine of the Cordoba Observatory states that Winnecke's comet on Dec. 13 was becoming too faint to be followed with the 12-inch refractor and that as it was moving rapidly northward, it might be possible for some of the large telescopes in northern observatories to observe the comet before its disappearance. The correction to Hillebrand's ephemeris on Dec. 10 was R.A. −55^s, Decl. 0′.

Ephemeris of Winnecke's Comet.

[By C. Hillebrand in *A. N.* 4386.]

		α app. h	m	s	δ app. °	′	log *r*	log Δ	1:$r^2\Delta^2$
Mar.	1	0	41	01	−9	31.5	0.31216	0.45845	0.029
	5	0	49	07	8	34.9	0.31971	0.46674	0.027
	9	0	57	01	7	40.0	0.32708	0.47471	0.025
	13	1	04	46	6	46.6	0.33429	0.48236	0.023
	17	1	12	20	5	55.0	0.34133	0.48968	0.022
	21	1	19	45	5	04.9	0.34821	0.49667	0.020
	25	1	27	01	4	16.6	0.35493	0.50335	0.019
	29	1	34	13	3	29.9	0.36151	0.50969	0.018
April	2	1	41	10	−2	44.8	0.36794	0.51794	0.017

Elliptic Elements of Comet *e* 1909 (Daniel).—In *A. N.* 4384 Mr. M. Ebell gives elliptic elements of this comet computed from observations on the dates Dec. 8, Jan. 2 and 14. These, however, fail to represent observations made at Goodsell Observatory Feb. 1 and 2, the correction to the ephemeris being nearly +10^m in R. A. and +24′ in Decl. The comet is exceedingly faint now.

Epoch = 1909 Dec. 8.5 Berlin
M = 1° 28′ 33″.3
ω = 3 36 32 .0
Ω = 70 58 16 .5 } 1910.0
i = 19 23 23 .7
ϕ = 36 50 02 .4
μ = 554″.178
log a = 0.537572
T = 1909 Nov. 28.91228 Berlin
Period = 6.403 years.

Comet *a* 1910.—The new comet in the west has diminished rapidly in brightness, and has not gone as far north as indicated in the ephemeris given in our last number. Elements received by telegram Feb. 7, computed by Morgan of the U. S. Naval Observatory, differ greatly from those given before, but these too fail to represent the observed positions of the comet in February, and must be regarded as very inexact. Another set of elements, computed by Professor H. A. Howe of the University of Denver, was received a few days later. These too fail to represent the observations in February.

ELEMENTS OF COMET *a* 1910.

Computer : Morgan.	Computer : Howe.
T = 1910 Jan. 27.18	1910 Jan. 29.158
Ω = 46° 0′	53° 37′.6
ω = 114 08	114 23 .3
i = 130 42	130 10 .5
q = 0.386	0.3864
Dates of observations : Jan. 16, 25, Feb. 2	Dates of observations : Jan. 16, 24, Feb. 1

EPHEMERIS.

G. M. T. 1910	R. A. h	m	Decl. °	′	log Δ	log *r*	Br.
Feb. 5.5	21	44	+4	7	0.083	9.664	
7.5	21	45	4	2	0 108	9.692	
9.5	21	46	3	50	0.131	9.721	
11.5	21	47	+3	34	0.150	9.749	0.09

It has been difficult to get good photographs of the comet on account of the low altitude and the strong twilight in which the exposure must be made. Nor can the position of the comet be determined with much accuracy from the

photographs, because of the varying absorption and refraction near the horizon. The star trails shown are very few and very unequal at the beginning and end.

The spectrum of the comet was observed visually by Frost on January 24 with the Bruce spectrograph of the Yerkes observatory. "Bright band spectrum conspicuous, with bright sodium lines. Parkhurst and Slocum obtained two spectrograms. The first shows very conspicuously the third cyanogen band and the other familiar ones. Continuous spectrum not relatively strong; sodium lines conspicuous. Four degrees extent of tail on both plates. Barnard's photograph showed nine degrees extent of tail." (Harvard Bulletin 386).

A telegram dated Jan. 31, 1910 was sent out from the Lick Observatory giving the following announcement: "Albrecht photographed spectrum of Comet *a* 1910 January 27.6. Bright sodium lines displaced toward red one and three-tenths tenth-meters, corresponding to a radial velocity relative to Earth of plus sixty-six kilometers." This indicates that the comet on Jan. 27 was receding from us at the rate of sixty-six kilometers and agrees with the indications from its rapid waning in brightness and its lessening apparent motion across the sky.

The following rough positions of the comet have come to hand from the Harvard Bulletin and other sources:

Greenwich M. T. 1910	h	m	α h	m	s	δ °	′	Observer	Place
Jan. 16	19	29.2	19	50	28	−25	9	Innes	Johannesburg
	20	23.0	19	51	8	25	4	Innes	Johannesburg
	22	16.2	19	52	23	24	54	Innes	Johannesburg
	23	56.5	19	53	32	24	42	Innes	Johannesburg
17	23	35.0	20	11	16	21	23	Jaschke & Krumpholz	Vienna
18	3	59.0	20	14	12	20	53	Bianchi	Rome
19	10	15	20	23		16.2		Campbell	Cambridge
20	10	26	20	45		13.2		Campbell	Cambridge
20	10	28	20	45		13.1		Wendell	Cambridge
20	11	39	20	45.7		12	50	Wilson	Northfield
20	13	30	20	52	3	12		Douglass	Flagstaff
21	11	11	20	54	5	10	21	Wilson	Northfield
21	11	18	20	55		10.5		Barnard	Williams Bay
21	11	33	20	55		10.5		Parkhurst	Williams Bay
21	13	40	20	58.4		10		Douglass	Flagstaff
22	12	8	21	2.0		7	55	Wilson	Northfield
22	13	44	21	3.7		8.0		Douglass	Flagstaff
24	—	—	21	15		4.6		Barnard	Williams Bay
24	13	38	21	13	23	4.5		Douglass	Flagstaff
25	11	53	21	19		3.2		Barnard	Williams Bay
25	12	0	21	17	40	3	7	Wilson	Northfield
25	13	20	21	18	05	3.1		Douglass	Flagstaff
26	13	26	21	21	56	2.0		Douglass	Flagstaff
27	11	42	21	25	11	0	47	Wilson	Northfield
27	13	24	21	26	07	− 0.85		Douglass	Flagstaff
28	10	40	21	28		0.0		Campbell	Cambridge
28	13	38	21	29	24	+ 0.1		Douglass	Flagstaff
29	13	39	21	31	23	1.0		Douglass	Flagstaff
30	10	45	21	34		1.8		Campbell	Cambridge
30	10	53	21	33		1.8		Wendell	Cambridge
30	13	43	21	34	05	1.85		Douglass	Flagstaff
31	12	19	21	37.4		2	35	Slocum	Williams Bay
31	13	44	21	36	39	2.6		Douglass	Flagstaff
Feb. 2	10	49	21	42		3.7		Campbell	Cambridge
4	10	54	21	44	39	4	56	Campbell	Cambridge
5	13	6	21	45	28	5	27	Wilson	Northfield
10	11	11	21	54	24	+ 7	42	Campbell	Cambridge

These positions are in most cases the results of circle readings of the telescopes, and are not corrected for index errors or refraction. Those obtained t Northfield have been corrected for refraction. The positions have been plotted

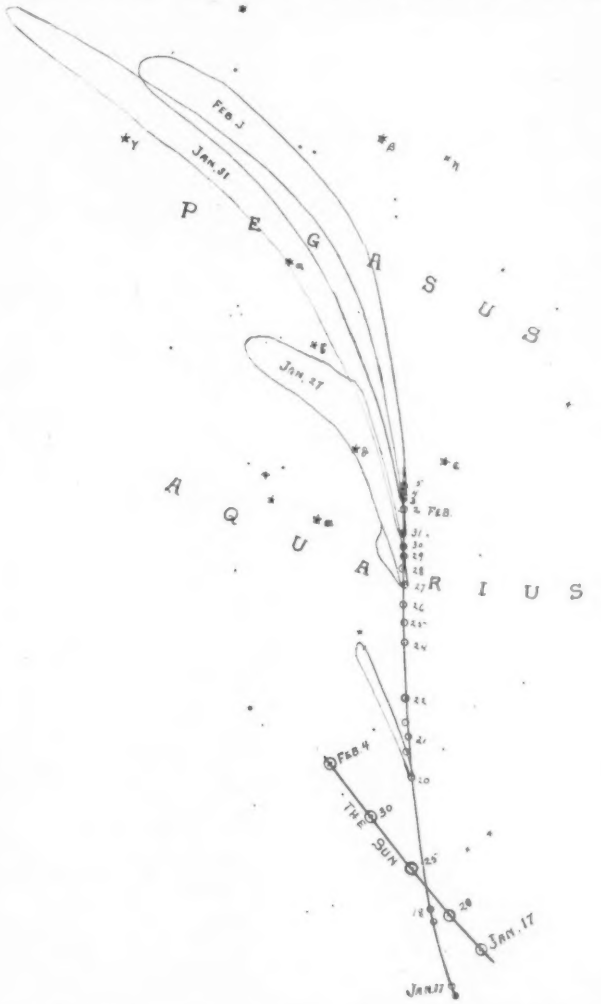
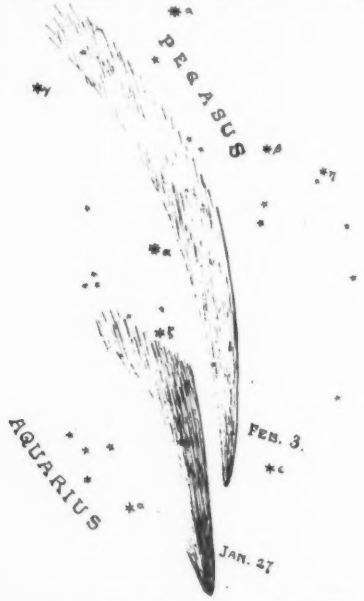


DIAGRAM SHOWING APPARENT PATH OF COMET *a* 1910 AND OUTLINE OF TAIL AS SKETCHED BY H. C. WILSON.

on the accompanying chart and show that the comet's motion, since it passed the Sun, has been almost along the arc of a great circle inclined about 40° to the ecliptic. The approximate outline of the tail of the comet as seen at Northfield

on four nights is sketched on the diagram. On Jan. 20 the tail was brightest but was seen against a bright background of twilight and in nearly full moonlight, so that the extent seen was only about ten degrees. On Jan. 27 the length of the tail as measured on the diagram is about 25°; on Jan. 30, 31 and Feb. 2 it could be traced to certainly 40° and possibly to 50° or more, the greater part of the extension being so faint and so close to the Zodiacal Light as to be scarcely distinguishable from the latter. By Feb. 9 the faint extensions of the tail were scarcely visible and the motion of the comet had slowed up so as to bring it too deep into the twilight to be easily seen before it set.



SKETCHES OF COMET *a* 1910 BY H. C. WILSON.

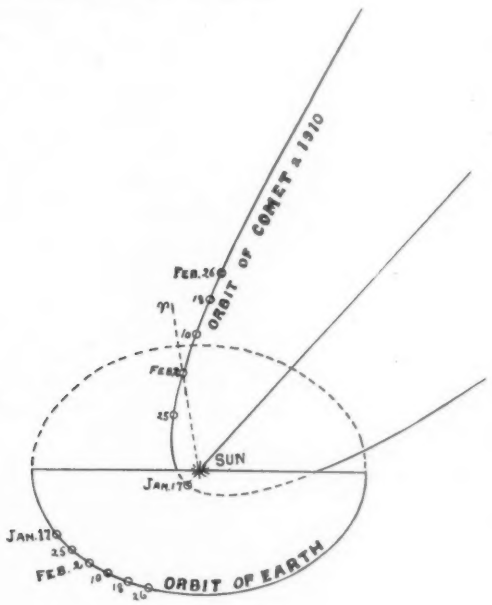
The following positions appear to have been determined with accuracy sufficient to permit their use in the computation of an orbit :

Date	Gr. m. t. h m	α app. h m s	δ app. ° ′ ″		
Jan. 17	22 16.3	19 52 23.07	—24 54 17	Innes	Johannesburg
18	0 11.9	20 12 07.07	21 16 51	Ramband	Algiers
19	0 23.9	20 28 01.87	17 43 42	Gonnessiat	Algiers
20	0 32.6	20 40 43.53	14 25 49	Gonnessiat	Algiers
22	4 56.3	20 59 59.31	8 15 23	Ernst	Heidelberg
23	(5 24.0)	21 6 21.07	6 49 29	Graff	Bergedorf (local time)
23	4 48.3	21 6 22.67	6 49 21	Schiller	Bothkamp
23	5 16.7	21 6 28.69	6 46 51	Milloswich	Rome
26	4 32.3	21 20 28.84	2 20 52	Struve and Guthnick	Berlin
26	5 55.8	21 20 41.72	— 2 16 35	Van Biesbrock	Uccle
		1910 0	1910.0		
Feb. 1	11 09.1	21 38 33.0	+ 3 13 49	Wendell	Cambridge
6	11 18.8	21 48 11.7	5 59 44	Wendell	Cambridge
10	11 21.5	21 54 26.0	+ 7 11 32	Wendell	Cambridge

Just as this number must go to press, a supplement to the *Astronomische Nachrichten* has come to hand with elements, computed by H. Kobold from the observations at Algiers Jan. 18 and 20 and those at Bergedorf and Bothkamp January 23.

$$T = 1910 \text{ Jan. } 17.108 \text{ Berlin m. t.}$$
$$\omega = 311^\circ\ 53'$$
$$\Omega = \ \ 83\ \ 59$$
$$i = 138\ \ 25$$
$$\log q = 9.0375$$

These elements represent the observations considerably better than Morgan's or Howe's but the errors in February are still large. According to Wendell's observation on Feb. 10 the correction to the ephemeris computed from these elements is $-1^m.4$ in R. A. and $-39'$ in Decl.



EPHEMERIS OF COMET *a* 1910.
[From Kobold's elements]

1910	α	δ	log *r*	log Δ	Δ*H*
	h m	° ′			m
Jan. 28	21 28.4	+0 13	9.6741	0.0854	+4.8
29	31.4	1 9			
30	34.2	2 1			
31	36.7	2 48			
Feb. 1	39.1	3 31	9.7716	0.1326	+5.5
2	41.4	4 12			
3	43.5	4 50			
4	45.5	5 25			
5	47.4	5 58	9.8460	0.1726	+6.1
6	49.2	6 30			

1910	α h m	δ ° ′	log r	log Δ	ΔH m
Feb. 7	21 51.0	6 59			
8	52.7	7 28			
9	54.3	7 54	9.9058	0.2068	+6.6
10	55.8	8 20			
11	57.3	8 45			
12	21 58.8	9 8			
13	22 0.2	9 31	9 9559	0 2365	+7.0
14	1.6	9 53			
15	22 2.9	+10 15			

ΔH signifies the number of magnitudes change in brightness from that on January 18.

The accompanying diagram of the orbit of the comet drawn according to Kobold's elements shows plainly why the comet appeared so suddenly and why it has so rapidly faded away. It came up to perihelion from behind the Sun, swept around swiftly, passing perihelion only about 10,000,000 miles from the Sun, and is now going almost straight away from us while our motion carries it behind the Sun again. By the time we get around to the other side of the Earth's orbit the comet will be so far out on its receding journey that it will be only a telescopic object if it is visible at all.

The Zodiacal Light and Comet *a* 1910.—The zodiacal light and Comet *a* 1910 presented a unique appearance on the nights of Jan. 30, 31 and Feb. 1 when the head of the comet was near to or below the horizon. The tail of the comet, especially near its end, resembled the zodiacal light so greatly that had one not known of the presence of the comet it might have appeared as a separated band of the light. On the night of Jan. 30 the general direction of the comet and the light showed a considerable angle of divergence; on the next night they appeared more nearly parallel, while on the night of Feb. 1, with the head of the comet at the horizon, its tail curved away gracefully then back again toward the light giving the suggestion very readily of a great bow with the tail of the comet forming its string.

Washburn Observatory, H. I. Woods.
Topeka, Kansas.

Comet *a* 1910.—The approximate position of Comet *a* 1910 was observed here on January 20, 21 and 23. The head of the comet was very near the horizon when it was picked up with the 11½-inch refractor on January 30. It showed a decided condensation, but no definite and clear cut nucleus was observed. The length of the tail was estimated at five degrees.

On January 21 the comet was observed through clouds with no very definite results.

On the 23d an attempt was made to observe the spectrum of the comet with a direct vision spectroscope attached to the 11½-inch. The continuous spectrum was clearly visible, and the presence of three bright lines, including that of sodium was suspected. On the same evening, independent measurements of the length of the tail were made by Professor Woods, Miss Brigham, Mr. Warner, and myself. The apparent length of the tail was still increasing as the western glow faded out, when at a little after 7 o'clock, C. S. T., a thin band of cloud obscured the comet and rendered further observations impossible. The mean of seven observations taken from 6:45 to 7:00 is 7.3 degrees. Mr.

Warner's mean is 6°.3, that of the writer is 7°.9, and that of Professor Woods is 8°.4. No doubt the tail could have been traced to a still greater distance if the moonlight had not been so bright. The measurements were made with a simple piece of apparatus which is capable of an accuracy of two or three-tenths of a degree. Our astronomy class will probably continue the observations of the length of the tail as long as it is sufficiently brilliant to be observed. The tail stood almost vertically in the west, and the extreme end was observed to have a decided curve to the southward. G. B. BLAIR.

Washbnrn College Observatory,
Topeka, Kansas, Jan. 24, 1910.

Length of Tail of Comet *a* 1910 as measured at Washburn College.

Date	Mean Length	Extreme Variation	No. of Observers	Remarks
Jan. 23	7.3°	5.6°— 8.8°	3	Bright Moonlight
26	22.3	19.5—26.5	4	" "
27	27.6	25 —33.5	4	
30	25.8	25.0—28.0	3	
31	21.5	20.8—22.5	3	
Feb. 4	16.5		1	

On all the dates given above, except the last, at least three observers took part in the measures. G. B. BLAIR.

Washburn Observatory, Topeka, Kansas.

Comet *a* 1910.—As January weather here was more favorable to vegetation than to star-gazing, it was only towards the end of the month that Comet *a* 1910 became discernible. On the evenings of the 26th and 27th, it glimmered faintly above the ocean mists and 7 o'clock was lost to view. Somewhat appropriately the apparition was within the constellation of the winged Horse, for seldom have comets of its size such a brief career of visibility.

COMET *a* 1910
Jan. 30, 6:45 P. M.

On very clear evenings it seemed to extend nearly to the Square of Pegasus, as represented in the illustration, was bounded on the south by the stars Zeta and Theta, and in width reached to half-way between the latter star and Epsilon in the same constellation. With head downward, tail erect, feathery, but not noticeably branching (perhaps owing to the mists of the Pacific) its dim outline seemed like a phantom comet to those who can recall the brilliant visitor of 1881, or who are familiar with descriptions of those of 1858 and 1843. The nucleus was bright and starlike, but the luster of the tail had more resemblance to an average streak of the Milky Way than to the golden train attributed to most of these celestial wanderers of unusual size. Being about thirty degrees distant from the position of Halley's comet, it is probable that its appearance at the same time is merely an interesting coincidence; though a tendency to follow in the same path as that of the great comet of 1843 has been noticed in several cometary visitors of the past century. As the motion of Comet *a* is N. E., its declining stages may be viewed telescopically before spring is past. ROSE O'HALLORAN.

San Francisco, California.

Perturbations of Halley's Comet.—In *A. N.* 4377 Professor A. A. Iwanow of St. Petersburg gives results of computations of the perturbations of the orbit of Halley's comet by the major planets during the interval from 1835 to 1910. He obtains for his final definitive elements for the epoch Dec. 13.0, 1909, Berlin mean time:

$$\left.\begin{array}{rl} M = & 358^\circ\ 18'\ 33''.76 \\ \pi = & 168\ \ 58\ \ 54\ .66 \\ \omega = & 111\ \ 41\ \ 59\ .46 \\ \Omega = & \ \ 57\ \ 16\ \ 55\ .20 \\ i = & 162\ \ 13\ \ 38\ .19 \end{array}\right\} 1910.0$$

$$\phi = 75\ 18\ 37\ .38$$

$$\mu = 46''.6718$$

These agree very closely with those obtained by Messrs. Cowell and Crommelin and bring the predicted time of perihelion on April 23 only three days later than it appears to be about to actually occur.

Ephemeris of Halley's Comet.

1910	R. A. h	m	s	Decl. °	′	log *r*	log Δ
April 4	0	5	38	+ 8	1	9.8369	0.2144
8	0	1	43	7	58	9.8101	0.1910
12	23	57	58	7	53	9.7883	0.1617
16		54	24	7	49	9.7738	0.1257
20		51	44	7	46	9.7688	0.0808
24		50	20	7	47	9.7757	0.0272
28		50	53	7	56	9.7911	9.9609
May 2	23	54	32	8	18	9.8146	9.8796
6	0	3	6	9	5	9.8363	9.7779
10		21	35	10	30	9.8654	9.6437
11		29	39	11	2		9.6049
12		38	32	11	41		9.5609
13	0	50	12	12	29	9.8877	9.5134
14	1	5	47	13	27		9.4618
15	1	24	47	14	36		0.4086
16	1	49	52	15	59		9.3501
17	2	23	4	17	29	9.9176	9.2945
18	3	7	19	18	51		9.2388
19	4	3	11	19	43		9.1993
20	5	3	23	19	8		9.1873
21	6	9	54	17	40	9.9468	9.1993
22	7	3	4	15	14		9.2388
23	7	44	48	12	40		9.2921
24	8	18	20	10	24		9.3480
25		40	7	8	31	9.9751	9.4049
26	8	58	52	6	59		9.4601
27	9	13	8	5	45		9.5120
28		24	36	4	45		9.5583
29		33	48	3	50	0.0049	9.6037
30	9	41	23	+ 3	15		9.6405

Astronomische Nachrichten, No. 4379. A. C. D. CROMMELIN.

The Tail of Halley's Comet.—In a private letter Professor Barnard says: "From my photographs with the ten-inch Bruce camera

Length of tail of Halley's comet on Feb. 3 and 10 = 5,000,000 miles
Diameter of head " " " Feb. 3 = 188,000
" " " " " " 10 = 194,000

This considerable length of tail so early (over two months before perihelion) gives hopes that on May 18 there will be plenty of tail to reach to and beyond the Earth."

Halley's Comet. Persistent cloudiness in the western sky hindered observations of Halley's comet until January 27 when it was recognized about two degrees northward from Zeta and Theta in the constellations of the Fishes.

As the writer has been looking forward to its coming for a quarter of a century, the first view evoked sentiments of greater depth and range than those that accompany the customary observations. Small, dim, irregular in outline with a nucleus just discernible, it was still the historic wanderer returned after an absence of 75 years. It was seen repeatedly since, and in the eight-inch refractor of the Chabot Observatory, Oakland, any extension that might be regarded as the beginnings of a tail were looked for carefully by the writer on January 28, but such an appendage could not be discerned.

San Francisco, California. ROSE O'HALLORAN.

Numbering and Elements of Minor Planets.—In *A. N.* 4380 Professor P. V. Neugebauer assigns numbers to seventeen more asteroids whose elements have been computed from a sufficient number of observations to identify them. The first two are numbers which were last year assigned to planets which have been since identified with those already known.

Provis. Designation		Number		Provis. Designation		Number	
1907 AG	=	(645)		1908 DN	=	(667)	
1907 BF	=	(655)		1908 DO	=	(668)	
1908 CC	=	(660)		1908 DQ	=	(669)	
1908 CL	=	(661)		1908 DR	=	(670)	
1908 CW	=	(662)	Newtonia	1908 DV	=	(671)	
1908 DG	=	(663)		1908 DY	=	(672)	
1908 DH	=	(664)		1908 EA	=	(673)	
1908 DK	=	(665)		1908 EP	=	(674)	Rachel
1908 DM	=	(666)					

ELEMENTS OF MINOR PLANETS.

No.	Epoch and Osc.	M			ω			Ω		
		°	′	″	°	′	″	°	′	″
(661)	1908 Feb. 26.5	20	26	07.8	154	47	09.0	336	48	24.2
(663)	June 27.5	78	04	18.6	308	37	06.3	233	46	58.4
(664)	June 27.5	6	21	50.5	90	04	28.3	175	51	38.6
(665)	July 27.5	40	38	57.9	314	27	08.2	299	49	27.4
(666)	July 27.5	314	31	43.3	171	02	01.5	215	34	41.9
(667)	Aug. 24.5	236	16	13.3	304	30	08.7	153	54	14.8
(668)	Aug. 21.5	358	03	09.6	108	22	10.7	216	02	50.2
(669)	Aug. 27.5	53	59	09.5	99	54	09.0	171	20	12.8
(670)	Nov. 15.0	356	26	39.5	191	28	40.9	175	10	26.8
(671)	Sept. 28.5	289	12	29.5	82	02	50.6	1	40	08.7
(672)	Sept. 24.5	54	53	25.9	308	21	08.9	344	02	11.5
(673)	Sept. 24.5	265	57	47.1	228	16	08.8	228	09	40.5

No.	i			ψ			μ	log a
	°	′	″	°	′	″	″	
(661)	9	20	55.0	2	22	32.7	678.143	0.479124
(663)	17	45	16.5	8	42	58.5	659.479	0.487204
(664)	8	31	05.8	14	02	19.2	628.749	0.501020
(665)	14	38	07.4	9	49	56.3	634.836	0.498231
(666)	7	34	09.7	13	56	19.3	850.116	0.413686
(667)	25	16	00.5	9	49	23.3	618.029	0.505998
(668)	6	48	13.0	13	20	26.6	759.640	0.446266
(669)	10	54	45 5	6	05	53.4	676.435	0.479854
(670)	7	32	37.2	11	16	55.6	756.023	0.447648
(671)	7	52	45.8	4	55	25.3	642.815	0.494614
(672)	11	00	17.5	7	28	02.9	871.386	0.406530
(673)	2	49	46.9	0	37	43.5	750.907	0.449614

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours, etc. For stars marked with an * alternate minima are given; ** every third minimum; † every tenth minimum.]

SY Androm.

	d	h
Apr.	10	21

*U Cephei

Apr.	4	18
	9	18
	14	17
	19	17
	24	17
	29	16

*Z Persei

Apr.	1	14
	7	16
	13	19
	19	22
	26	0

RY Persei

Apr.	3	21
	10	17
	17	14
	24	11

**RZ Cassiop.

Apr.	2	15
	6	5
	9	19
	13	9
	16	23
	20	13
	24	4
	27	18

*ST Persei

Apr.	3	15
	8	22
	14	5
	19	13
	24	20
	30	3

RX Cephei

Apr.	9	11

*β Persei

Apr.	1	8
	7	2
	12	20
	18	13
	24	7
	30	1

**RT Persei

Apr.	1	18
	4	7
	6	20

RT Persei

	d	h
Apr.	9	9
	11	22
	14	11
	17	1
	19	14
	22	3
	24	16
	27	5
	29	18

λ Tauri

Apr.	1	10
	5	9
	9	8
	13	7
	17	5
	21	4
	25	3
	29	2

*RW Tauri

Apr.	3	14
	9	3
	14	16
	20	5
	25	18

*RV Persei

Apr.	1	18
	5	16
	9	15
	13	14
	17	13
	21	11
	25	10
	29	9

RW Persei

Apr.	2	5
	13	10
	24	15

RS Cephei

Apr.	5	12
	17	22
	30	8

*RY Aurigæ

Apr.	3	16
	9	3
	14	14
	20	1
	25	12
	30	22

*RZ Aurigæ

	d	h
Apr.	2	6
	8	7
	14	8
	20	9
	26	9

*RW Gemin.

Apr.	2	0
	7	18
	13	11
	19	5
	24	22
	30	16

*U Columbæ

Apr.	2	15
	8	5
	13	19
	19	10
	25	0
	30	15

RW Monoc.

Apr.	1	7
	5	3
	8	22
	12	18
	16	13
	20	9
	24	4
	28	0

RX Geminorum

Apr.	1	15
	13	20
	26	1

**RU Monoc.

Apr.	1	10
	4	2
	6	19
	9	11
	12	4
	14	20
	17	13
	20	5
	22	22
	25	14
	28	7

RY Geminorum

Apr.	6	16
	15	23
	25	6

**R Canis Maj.

	d	h
Apr.	1	16
	5	1
	8	11
	11	21
	15	7
	18	17
	22	2
	25	12
	28	22

*Y Camelop.

Apr.	3	16
	10	7
	16	22
	23	12
	30	3

RR Puppis

Apr.	2	5
	8	15
	15	1
	21	12
	27	22

**V Puppis

Apr.	1	14
	5	23
	10	7
	14	16
	19	1
	23	9
	27	18

†X Carinæ

Apr.	1	19
	7	5
	12	15
	18	1
	23	11
	27	18

S Cancri

Apr.	3	6
	12	17
	22	5

S Velorum

Apr.	3	6
	9	4
	15	3
	21	1
	26	23

**Y Leonis

	d	h
Apr.	2	8
	7	9
	12	11
	17	12
	22	14
	27	15

**RR Velorum

Apr.	1	15
	7	4
	12	18
	18	7
	23	21
	29	10

*SS Carinae

Apr.	2	21
	9	12
	16	2
	22	17
	29	7

RW Urs. Maj.

Apr.	5	15
	12	22
	20	6
	27	14

**Z Draconis

Apr.	1	7
	5	8
	9	10
	13	12
	17	13
	21	15
	25	17
	29	19

*SS Centauri

Apr.	3	1
	8	1
	13	0
	17	23
	22	22
	27	21

*δ Libræ

Apr.	1	5
	5	20
	10	12
	15	4
	19	19
	24	11
	29	3

Minima of Variable Stars of the Algol Type.—Continued.

*U Coronæ	d	h
Apr.	2	2
	9	0
	15	22
	22	19
	29	17

*SW Ophiuchi	d	h
Apr.	1	2
	6	0
	10	21
	15	19
	20	16
	25	13
	30	11

*SX Ophiuchi	d	h
Apr.	2	13
	6	16
	10	19
	14	22
	19	1
	23	4
	27	7

R Aræ	d	h
Apr.	2	12
	6	23
	11	9
	15	19
	20	5
	24	15
	29	2

**U Ophiuchi	d	h
Apr.	1	2
	3	14
	6	2
	8	15
	11	3
	13	16
	16	4
	18	16
	21	5
	23	17
	26	5
	28	18
	30	6

**SZ Herculis	d	h
Apr.	1	13
	4	0

SZ Herculis	d	h
Apr.	6	11
	8	22
	11	9
	13	20
	16	7
	18	18
	21	5
	23	15
	26	2
	28	13

Z Herculis	d	h
Apr.	2	1
	6	1
	10	1
	14	1
	18	1
	22	0
	26	0
	30	0

*RS Sagittarii	d	h
Apr.	3	0
	7	20
	12	16
	17	12
	22	8
	27	4

*V Serpentis	d	h
Apr.	2	4
	9	1
	15	23
	22	21
	29	19

†RZ Draconis	d	h
Apr.	2	0
	7	15
	13	0
	18	12
	24	1
	29	13

**RX Herculis	d	h
Apr.	1	2
	3	18
	6	10
	9	2
	11	18
	14	10
	17	2
	19	18

RX Herculis	d	h
Apr.	22	10
	25	2
	27	18
	30	10

*SX Sagittarii	d	h
Apr.	2	14
	6	18
	10	22
	15	1
	19	5
	23	9
	27	12

*RR Draconis	d	h
Apr.	2	23
	8	15
	14	7
	19	23
	25	15

RZ Aurigae	d	h
Apr.	7	0

**U Scuti	d	h
Apr.	1	21
	4	18
	7	15
	9	12
	13	8
	16	5
	19	2
	21	23
	24	19
	27	16
	30	13

*RX Draconis	d	h
Apr.	1	19
	5	14
	9	9
	13	4
	16	23
	20	18
	24	13
	28	8

*RV Lyræ	d	h
Apr.	2	3
	9	8
	16	13
	23	18
	30	22

*U Sagittae	d	h
Apr.	1	6
	8	0
	14	18
	21	13
	28	7

Z Vulpeculæ	d	h
Apr.	3	0
	8	2
	13	3
	18	4
	23	5
	28	6

SY Cygni	d	h
Apr.	3	1
	9	2
	15	2
	21	2
	27	2

*WW Cygni	d	h
Apr.	4	6
	10	21
	17	12
	24	3
	30	19

ZW Cygni	d	h
Apr.	3	12
	8	1
	12	15
	17	5
	21	19
	26	8
	30	22

VW Cygni	d	h
Apr.	6	4
	14	15
	23	1

*UW Cygni	d	h
Apr.	3	7
	10	5
	17	3
	24	0
	30	22

W Delphini	d	h
Apr.	3	2
	8	21
	13	17
	17	12

W Delphini	d	h
Apr.	22	7
	27	3

RR Delphini	d	h
Apr.	5	12
	10	3
	14	17
	19	7
	23	22
	28	12

RR Vulpeculae	d	h
Apr.	5	2
	10	3
	15	5
	20	6
	25	7
	30	8

**VV Cygni	d	h
Apr.	1	21
	6	7
	10	18
	15	4
	19	14
	24	1
	28	11

UZ Cygni	d	h
Apr.	18	4

*RT Lacertae	d	h
Apr.	3	1
	8	3
	13	5
	18	6
	23	8
	28	10

*TT Androm.	d	h
Apr.	1	18
	7	6
	12	19
	18	8
	23	20
	29	9

21.1909 Andr.	d	h
Apr.	2	23
	7	2
	11	5
	15	8
	19	10
	23	13
	27	16

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

SX Cassiop.	d	h
Apr.	27	9

SY Cassiop.	d	h
Apr.	4	10

SY Cassiop.	d	h
Apr.	8	12

SY Cassiop.	d	h
Apr.	12	13

SY Cassiop.	d	h
Apr.	16	15

Maxima of Variable Stars of Short Period not of the Algol ype.-Con.

SY Cassiop.

	d	h
Apr.	20	17
	24	18
	29	20

RW Cassiop.

	d	h
	(−5	19)
Apr.	2	12
	17	7

SU Cassiop.

	d	h
	(−0	22)
Apr.	2	15
	4	14
	6	13
	8	12
	10	11
	12	9
	14	8
	16	7
	18	6
	20	4
	22	3
	24	2
	26	1
	27	23
	29	22

SV Persei

	d	h
Apr.	4	8
	15	11
	26	14

RX Aurigæ

	d	h
	(−4	0)
Apr.	6	23
	18	14
	30	5

SX Aurigae

	d	h
Apr.	1	3
	2	16
	4	5
	5	18
	7	6
	8	19
	10	8
	11	21
	13	9
	14	22
	16	11
	17	24
	19	12
	21	1
	22	14
	24	3
	25	16
	27	4
	28	17
	30	6

SY Aurigae

	d	h
Apr.	4	0
	14	3
	24	7

Y Aurigæ

	d	h
	(−0	18)
Apr.	4	9
	8	6
	12	3
	15	23
	19	20
	23	17
	27	13

RZ Geminorum

	d	h
	(−1	7)
Apr.	3	7
	8	19
	14	7
	19	20
	25	8
	30	20

RS Orionis

	d	h
	(−2	0)
Apr.	2	17
	10	7
	17	20
	25	10

T Monoc.

	d	h
	(−9	23)
Apr.	1	18
	28	18

W Geminorum

	d	h
	(−2	2)
Apr.	5	23
	13	21
	21	19
	29	17

ζ Geminorum

	d	h
	(−5	0)
Apr.	1	16
	11	19
	21	23

RU Camelop.

	d	h
	(−9	12)
Apr.	16	1

V Carinæ

	d	h
	(−2	4)
Apr.	7	8
	14	1
	20	18
	27	10

T Velorum

	d	h
	(−1	10)
Apr.	4	15
	9	6
	13	21
	18	13
	23	4
	27	19

W Carinæ

	d	h
	(−1	0)
Apr.	1	3
	5	12

W Carinae

	d	h
Apr.	9	21
	14	6
	18	15
	22	24
	27	9

S Muscæ

	d	h
	(−3	11)
Apr.	4	11
	14	2
	23	18

T Crucis

	d	h
	(−2	2)
Apr.	2	17
	9	10
	16	4
	22	21
	29	15

R Crucis

	d	h
	(−1	10)
Apr.	4	23
	10	18
	16	14
	22	10
	28	6

S Crucis

	d	h
	(−1	12)
Apr.	2	18
	7	11
	12	3
	16	20
	21	13
	26	5
	30	22

RZ Centauri

	d	h
Apr.	1	12
	2	11
	3	9
	4	8
	5	6
	6	5
	7	3
	8	2
	9	0
	9	23
	10	21
	11	20
	12	18
	13	17
	14	15
	15	14
	16	12
	17	11
	18	9
	19	8
	20	6
	21	5
	22	3
	23	2
	24	1

RZ Centauri

	d	h
Apr.	24	23
	25	22
	26	20
	27	19
	28	17
	29	16
	30	14

W Virginis

	d	h
	(−8	5)
Apr.	8	9
	25	16

V Centauri

	d	h
	(−1	11)
Apr.	4	21
	10	9
	15	15
	21	3
	26	15

R Triang. Austr.

	d	h
	(−1	0)
Apr.	1	13
	4	22
	8	8
	11	17
	15	2
	18	12
	21	21
	25	6
	28	16

S Triang. Austr.

	d	h
	(−2	2)
Apr.	4	16
	11	0
	17	8
	23	16
	29	23

S Normæ

	d	h
	(−4	10)
Apr.	2	16
	12	10
	22	4

RV Scorpii

	d	h
	(−1	10)
Apr.	4	10
	10	11
	16	13
	22	14
	28	16

RV Ophiuchi Minimum

	d	h
Apr.	3	11
	7	3
	10	20
	14	12
	18	4
	21	21
	25	13
	29	6

X Sagittarii

	d	h
	(−2	22)
Apr.	2	6
	9	6
	16	6
	23	7
	30	7

Y Ophiuchi

	d	h
	(−6	5)
Apr.	15	8

W Sagittarii

	d	h
	(−3	0)
Apr.	5	18
	13	8
	20	22
	28	12

Y Sagittarii

	d	h
	(−2	2)
Apr.	3	22
	9	17
	15	11
	21	6
	27	0

U Sagittarii

	d	h
	(−2	23)
Apr.	4	3
	10	21
	17	15
	24	9

β Lyræ

	d	h
	(−3	7)
	(−3	2)
Apr.	3	5
	9	21
	16	3
	22	19
	29	1

κ Pavonis

	d	h
	(−4	7)
Apr.	4	1
	13	4
	22	6

U Aquilæ

	d	h
	(−2	4)
Apr.	5	13
	12	13
	19	14
	26	14

U Vulpeculæ

	d	h
	(−2	3)
Apr.	2	21
	10	20
	18	20
	26	19

SU Cygni

	d	h
	(−1	7)
Apr.	1	17
	5	14

Maxima of Variable Stars of Short Period not of the Algol Type.

Continued.

SU Cygni

	d	h
Apr.	9	10
	13	6
	17	2
	20	23
	24	19
	28	15

η Aquilae (−2 6)

	d	h
Apr.	5	1
	12	5
	19	10
	26	14

S Sagittae (−3 10)

	d	h
Apr.	4	15
	13	0
	21	9
	28	19

X Vulpeculae (−2 1)

	d	h
Apr.	3	19
	10	3
	16	11
	22	18
	29	2

V Vulpeculae Minimum

	d	h
Apr.	30	4

X Cygni (−6 19)

	d	h
Apr.	14	22

T Vulpeculae (−1 10)

	d	h
Apr.	2	22
	7	9
	11	19
	16	6
	20	16
	25	3
	29	13

TX Cygni

	d	h
Apr.	3	21
	18	14

VY Cygni (−2 14)

	d	h
Apr.	6	0
	13	21
	21	18
	29	14

VZ Cygni (−1 1)

	d	h
Apr.	2	4
	7	1
	11	22
	16	18
	21	15
	26	12

Y Lacertae (−1 10)

	d	h
Apr.	4	8
	8	15
	12	23
	17	7
	21	15
	25	23
	30	6

δ Cephei

	d	h
Apr.	2	0
	7	9
	12	18
	18	3
	23	12
	28	20

Z Lacertae

	d	h
Apr.	7	5
	18	2
	28	23

RR Lacertae (−1 2)

	d	h
Apr.	5	7
	11	17
	18	3
	24	13
	30	24

V Lacertae (−1 16)

	d	h
Apr.	2	11
	7	11
	12	10
	17	10
	22	10
	27	9

X Lacertae

	d	h
Apr.	5	21
	11	8
	16	19

X Lacertae

	d	h
Apr.	22	5
	27	16

SW Cassiop.

	d	h
Apr.	3	19
	8	19
	14	6
	19	16
	25	2
	30	13

RS Cassiop. (−1 19)

	d	h
Apr.	6	4
	12	12
	18	19
	25	2

RY Cassiop. (−7 10)

	d	h
Apr.	1	1
	13	5
	25	8

Approximate Magnitudes of Variable Stars on Feb. 1, 1910.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn.
X Androm.	0	10.8	+46	27	14.2	*o* Ceti	2	14.3	− 3	26	8.5
T Androm.		17.2	+26	26	14.0*d*	S Persei		15.7	+58	8	9.9
T Cassiop.		17.8	+55	14	8.5*d*	R Ceti		20.9	− 0	38	8.6 *i*
R Androm.		18.8	+38	1	10.4*d*	RR Persei		21.7	+50	49	13.5
S Ceti		19.0	− 9	53	11.5*d*	U Ceti		28.9	−13	35	7.0
Y Cephei		31.3	+79	48	13.0	RR Cephei		30.4	+80	42	13.0
U Cassiop.		40.8	+47	43	14.5*d*	R Trianguli		31.0	+33	50	11.8*d*
RW Androm.		41.9	+32	8	13.0	T Arietis		42.8	+17	6	9.3
V Androm.		44.6	+35	6	13.0 *i*	W Persei		43.2	+56	34	8.6 *i*
RR Androm.		45.9	+33	50	13.0 *i*	U Arietis	3	5.5	+14	25	9.3*i*
RV Cassiop.		47.1	+46	53	<14	X Ceti		14.3	− 1	26	8.8
W Cassiop.		49.0	+58	1	8.9	Y Persei		20.9	+43	50	9.9*d*
Z Ceti	1	1.6	− 2	1	12.0 *i*	R Persei		23.7	+35	20	8.5
U Androm.		9.8	+40	11	14.0*d*	T Tauri		16.2	+19	18	12.2 *i*
S Piscium		12.4	+ 8	24	<13	R Tauri		22.8	+ 9	56	11.8 *i*
S Cassiop.		12.3	+72	5	8.0	W Tauri		22.2	+15	49	10.7 *i*
U Piscium		17.7	+12	21	15.0	S Tauri	4	23.7	+ 9	44	<13
R Piscium		25.5	+ 2	22	10.3 *i*	T Camelop.		30.4	+65	57	8.8 *i*
RU Androm.		32.8	+38	10	11.6*d*	RX Tauri		32.8	+ 8	9	13.0
Y Androm.		33.7	+38	50	14.3*d*	X Camelop.		32.6	+74	56	11.8*d*
X Cassiop.		49.8	+58	46	10.0 *i*	V Tauri		46.2	+17	22	11.2*d*
U Persei		53.0	+54	20	9.0*d*	R Orionis		53.6	+ 7	59	9.3 *i*
S Arietis		59.3	+12	3	14.2*d*	R Leporis		55.0	−14	57	6.8*d*
R Arietis	2	10.4	+24	35	7.5	V Orionis	5	0.8	+ 3	58	9.9 *i*
W Androm.		11.2	+43	50	12.0*d*	R Aurigae		9.2	+53	28	9.8 *i*
Z Cephei		12.8	+81	13	10.7	S Aurigae		20.5	+34	4	8.9*d*

Approximate Magnitudes of Variable Stars on Feb. 1, 1910—Con.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A 1900 h	m	Decl. 1900 °	′	Magn.
W Aurigae	5	20.1	+36	49	<13.5	U Urs. Min.	14	15.1	+67	15	11.3*d*
S Orionis		24.1	— 4	46	8.8*d*	S Bootis		19.5	+54	16	12.0*d*
T Orionis		30.5	— 5	32	10.8	R Camelop.		25.1	+84	17	13.0
S Camelop.		30.2	+68	45	9.5 *i*	S Urs.Min.	15	33.4	+78	58	8.8 *i*
RR Tauri		33.3	+26	19	11.0	T Draconis	17	54.8	+58	14	8.5 *i*
U Aurigae		35.6	+31	59	10.3*d*	— Draconis		54.7	+54	13	11.0
SU Tauri		43.2	+19	2	<14	V Draconis	18	56.3	+54	53	14.0
Z Tauri		46.7	+15	46	11.6*d*	W Draconis		5.4	+65	56	14.0*d*
U Orionis		49.9	+20	10	11.8	X Draconis		6.8	+66	8	11.0*d*
V Camelop.		49.4	+74	30	<13	U Draconis	19	9.9	+67	7	9.0 *i*
Z Aurigae		53.6	+53	18	10.2	R Cygni		34.1	+49	58	11.6*d*
X Aurigae	6	4.4	+50	15	8.3	RT Cygni		40.8	+48	32	6.8 *i*
V Aurigae		16.5	+47	45	8.8	TU Cygni		43.3	+48	49	12.0*d*
V Monoc.		17.7	— 2	9	12.5*d*	Z Cygni		58.6	+49	46	10.5 *i*
R Monoc.		33.7	+ 8	49	11.5*d*	S Cygni	20	3.4	+57	42	13.8*d*
S Lyncis		35.9	+58	0	13	RS Cygni		9.8	+38	28	9.3*d*
X Gemin.		40.7	+30	23	8.5 i	U Cygni		16.5	+47	35	9.5*d*
W Monoc.		47.5	— 7	2	10.0	RW Cygni		25.2	+39	39	9.5
Y Monoc.		51.3	+11	22	11.2 *i*	ST Cygni		29.9	+54	38	10.6 *i*
X Monoc.		52.4	— 8	56	8.3	S Delphini		38.5	+16	44	10.0*d*
R Lyncis		53.0	+55	28	8.8	V Cygni		38.1	+47	47	10.0 *i*
RS Gemin.		55.2	+30	40	10.0	RZ Cygni		48.5	+46	59	11.5*d*
V Can. Min.	7	1.5	+ 9	2	14.0*d*	TW Cygni	21	1.8	+29	0	9.8 *i*
R Gemin.		1.3	+22	52	11.3*d*	X Cephei		3.6	+82	40	10.0
R Can. Min.		3.2	+10	11	7.7	T Cephei		8.2	+68	5	9.8*d*
RR Monoc.		12.4	+ 1	17	11.3*d*	S Cephei		36.5	+78	10	10.0*d*
V Gemin.		17.6	+13	17	<13	RU Cygni		37.3	+53	52	7.5 *i*
S Can. Min.		27.3	+ 8	32	12.0	RR Pegasi		40.0	+24	33	11 5*d*
T Can. Min.		28.4	+11	58	13.0	V Pegasi		56.0	+ 5	38	14.0
U Can. Min.		35.9	+ 8	37	9.8 *i*	T Pegasi	22	4.0	+12	3	9.0 *i*
S Gemin.		37.0	+23	41	10.5*d*	Y Pegasi		6.8	+13	52	13.5*d*
T Gemin.		43.3	+23	59	11.6 *i*	RS Pegasi		7.4	+14	4	13.0
U Puppis		56.1	−12	34	<14	RV Pegasi		21.0	+29	58	10.8*d*
R Cancri	8	11.0	+12	2	10.9*d*	S Lacertae		24.6	+39	48	12.4*d*
V Cancri		16.0	+17	36	9.1 i	R Lacertae		38.8	+41	51	9 5 *i*
RT Hydrae		24.7	— 5	59	8.2	RW Pegasi		59.2	+14	46	12.9
U Cancri		30.0	+19	14	10.4	R Pegasi	23	1.6	+10	0	11.7*d*
T Cancri		51.0	+20	14	9.0	V Cassiop.		7.4	+59	8	12.5
W Cancri	9	4.0	+25	39	9.2	W Pegasi		14.8	+25	44	10.0*d*
R Leo. Min.		39.6	+34	58	9.0	S Pegasi		15.5	+ 8	22	10.8 *i*
R Leonis		42.2	+11	54	9.3*d*	Z Androm.		28.8	+48	16	10.2
V Leonis		54.5	+21	44	12.0*d*	ST Androm.		33.8	+35	13	8.0 *i*
R Urs. Maj.	10	37.6	+69	18	11.5 *i*	Z Cassiop.		39.7	+56	2	11.5*d*
T Urs. Maj.	12	31.8	+60	2	7.5 *i*	RR Cassiop.		50.7	+53	8	10.5
RS Urs. Maj.		34.4	+59	2	<13	R Cassiop.		53.3	+50	50	6.4
S Urs. Maj.		39.6	+61	38	10.0*d*	Z Pegasi		55.0	+25	21	11.0*d*
T Urs.Min.	13	32.6	+73	56	13.0*d*	Y Cassiop.		58.2	+55	7	<14

The letter *i* denotes that the light is increasing; the letter *d*, that the light is decreasing; the sign <, that the variable is fainter than the appended magnitude. The above magnitudes have been compiled by Mr. Leon Campbell of the Harvard College Observatory from observations made at the Vassar, Mt. Holyoke, Swartz and Harvard Observatories.

Elements of the Variable 176.1907 Herculis.—In *A. N.* 4382 Mr. M. Luizet gives provisional elements determined from 136 observations of this variable, which appears to be of the Algol type except that it has two minima of unequal brightness and at unequal intervals. The total period or interval

between like minima is about $20^d\ 18^h.1$. The star's normal brightness is $8^m.9$; at the principal minimum it descends to $9^m.5$ and at the secondary minimum its magnitude is about 9.2. The secondary minimum follows the primary by 11.06 days while the interval from the secondary to the primary is 9.70 days. Mr. Luizet gives the following formula for the odd and even minima:

$$\left.\begin{matrix} m_1 = 2418132.39 \\ m_2 = 2418143.45 \end{matrix}\right\} + 20^d.755\ E.$$

The star is BD + 17°3117 and its position for 1900 is

$$\alpha = 16^h\ 49^m\ 54^s \qquad \delta = +17°\ 0'.$$

Elements of the Variable 16.1908 Vulpeculae.—In *A. N.* 4382 Mr. T. N. Astbury of Wallingford, England, gives elements of this variable determined from observations made near 22 minima during the years 1908-09.

$$\text{Minimum} = \text{J. D. } 2418287.24 + 4^d.4764\ E.$$

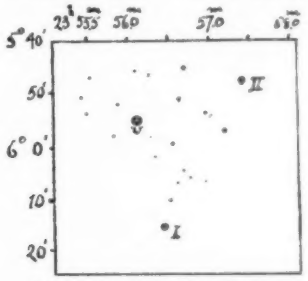
The star is of the Algol type and the observations are so scattered as to preclude the possibility of a shorter period. The range of variation is from $6^m.9$ to $8^m.0$. The star is AD + 22°3647 and its position for 1900.0 is

$$\alpha = 19^h\ 13^m\ 24^s.61 \qquad \delta = +22°\ 15'\ 40''.0.$$

Variable 43.1909 Draconis.—In *A. N.* 4381 Miss Mary W. Whitney of Vassar College Observatory states that the new variable discovered by her near SX Draconis is of the Algol type and has an approximate period of $5^h\ 4^h.27$. The last observed minimum must have occurred near Dec. 21 $18^h.56$ Gr. m. t. The duration of the phase appears to be about 14 hours.

New Variable 45.1909 Piscium.—This is announced in *A. N.* 4381 by Dr. E. Silbernagel of Munich and was found upon three photographic plates taken Sept. 19.1901 and Sept. 16 and 20, 1909. Its magnitude as indicated by the three plates was estimated at 14.5, 12.5 and 12.5. Its position for 1900.0 is

$$\alpha = 23^h\ 55^m\ 55^s \qquad \delta = +5°\ 54'.0.$$



VARIABLE 45.1909 PISCIUM.

The two brighter stars on the little chart are

I	BD + 5°5247	$23^h\ 56^m\ 15^s.98$	+6° 14′	5″.6 (1900)
II	BD + 5°5252	23 57 16 .77	+5 46	40 .0 (1900)

New Variable 46.1909 Pegasi.—In *A. N.* 4381 Professor W. Ceraski announces a new variable found upon the Moscow photographs. Six photographs yield the following magnitudes:

1909 Sept. 11	$9^m.2$	Oct. 15	$9^m.7$
16	9 .2	19	9 .7
22	9 .3	21	9 .9

The position of the variable for 1900.0 is

$$\alpha = 22^h\ 45^m\ 26^s \qquad \delta = +17^\circ\ 22'.$$

New Variable 1.1910 Pegasi.—This is the star DM +34°4598, and is announced as variable by Mr. Paul S. Yendell in *A. J.* 605. It is given in the DM as of magnitude 9.2, but on Nov. 30 Mr. Yendell found it to be invisible with a 4¼-inch telescope and on Dec. 5 although visible it was below 10^m. On subsequent nights it was below $10^m.5$.

In *A. N.* 4383 Mr. F. Küstner finds from an investigation of the original records of the DM that the two stars DM +33°4424 and +34°4598 were both observed on three nights, on two of which the former was estimated as 9.5 and the latter $9^m.0$ while on the third the estimates were $9^m.2$ and $9^m.5$ in the reverse order of brightness.

GENERAL NOTES.

A Large Nebula in Cetus.—In *A. N.* 4380 Professor Max Wolf calls attention to large faint nebula found upon photographs taken at Heidelberg, which seems to have been hitherto unknown. Its position for 1855.0 is roughly

$$\alpha = 23^h\ 54^m.6 \qquad \delta = -16^\circ\ 15'.$$

It extends about 15′ north and south, and is about 3′ wide east and west at the broadest part. It contains a number of nebular nuclei.

Orbit of 70 Ophiuchi.—In the Bulletin Astronomique for December, 1909, Mr. H. E. Lau gives the results of an extensive investigation of the binary system 70 Ophiuchi. The measures of this double star by many observers reveal apparent anomalies of movement of the pair which have led to the suspicion of a third component to the system. Mr. Lau, however, concludes that the anomalies are due to systematic errors in the measurement of position angles, which are common to the majority of observers, and so are not eliminated in taking the mean of the measures by a great number of observers.

He gives the following final results along with those recently published by Doberck and Lohse.

Elements of the Orbit of 70 Ophiuchi.

	Lau	Doberck	Lohse
Epoch of periastron	1896.09	1896.04	1895 91
Duration of one revolution	87.49	87.49	87.86 yrs.
Semimajor axis	4″.58	4″.54	4″.56
Eccentricity	0.500	0.499	0.499
Inclination	57°.94	59°.13	58°.57
Position of periastron	295°.87	294°.98	295°.89
Position of node	124°.26	122°.37	122°.96

A Substitute for the Cross-Staff. A piece of apparatus is in use here for the rough measurement of angles which has the advantage of the cross-staff in its extreme simplicity of construction, while measurements made with

it are probably quite as accurate as those made with the last named instrument. The material required consists of two yard sticks, such as many mercantile firms put out for advertising purposes, a bindingpost from a discarded dry cell, and two small screw eyes.

The yard sticks are hinged together at the corresponding ends by means of the binding post which is set at a distance of one inch from the ends of the sticks, and acts as a sort of pivot about which the sticks swing like the legs of a pair of dividers. The screw eyes act as sights, and are screwed into the free ends of the sticks also at a distance of one inch from the ends.

To take a measurement, the eye is placed close behind the hinged end, and the holes in the screw eyes are set as nearly as possible on the points whose angular separation is to be measured. Without disturbing the adjustment of the arms, the distance between two points on the arms equidistant from the pivot is read off in degrees and fractions of a degree by the use of a cardboard scale. The selected points may be more easily identified if they are surrounded by circles to catch the eye. For angles less than 40°, the reference points are 30 inches from the pivot; for angles from 40° to 90°, they are 15 inches from the pivot. It is convenient to place the scale which reads up to 40° on one edge of a strip of cardboard and that for the larger angles on the other. This arrangement makes it possible to read all angles up to 90°. In practice it will be found that a scale about 20 inches long, reading angles up to 40°, will be sufficient for most purposes. A moderate sized angle is easily measured with an error of not more than two or three tenths of a degree. If the instrument is used at night, a light must be placed behind the observer in order to render the sights visible. A member of our astronomy class, who is also taking ethics, has christened the device the moral yard stick.

The following table makes it a simple matter to construct the angles.

Length of Arm 30 inches.		Length of Arm 15 inches.	
Angle.	Dist. from Zero of Scale cm.	Angle.	Dist. from Zero of Scale in cm.
1	1.33 cm.	45	29.16 cm.
2	2 66	50	32.20
3	3.99	55	35.18
4	5.32	60	38.10
5	6.65	65	40.94
6	7.98	70	43.70
7	9.30	75	46.38
8	10.63	80	48.98
9	11.96	85	51.48
10	13.28	90	53.88
15	19 89		
20	26.46		
25	32.98		
30	39.44		
35	45.82		
40	52.12		
45	58.32		

Washburn College Observatory,
Topeka, Kansas.

G. B. Blair.

Halley's Comet. A Correction. In Popular Astronomy for February, 1910, on page 113, I am credited with being the first one to see Halley's comet at this return with the forty-inch telescope of the Yerkes Observatory. This is a mistake.

Professor S W. Burnham was the first astronomer to actually see the comet in the sky at its present return. His observations were made with the forty-inch telescope on the morning of September 16, 1909.

Yerkes Observatory, Jan. 28, 1910. E. E. Barnard.

How I Found Halley's Comet. Since my notes appeared in the November Popular Astronomy I have received some letters making inquires concerning the purchasing of a telescope and so it may be helpful if some suggestions are made.

An amateur should remember that the optical parts of a telescope are of the first importance. One should never be caught by the cheap prices that are

offered by some dealers. If one is limited in price, he better be contented with a smaller instrument than purchase an inferior one. In fact superior value in the lenses is worth more than extra inches in the diameter of the object glass. I purchased my 3½″ instrument through a reponsible dealer and as a result of trusting his superior judgment I have an instrument which accomplishes all that can be reasonably expected of its size. Epsilon Lyrae is a good test for a 3″ or a 3½″ telescope. I have succeeded in dividing it into its four components. One of the pairs is but 2″ apart. Some have asked if it is possible to purchase a second-hand telescope. Yes, often but in such cases, one needs to be careful and get quality. As a rule the telescope makers do not handle such instruments. If one is purchased from a private party then it is helpful to have the judgment of one expert along these lines, or at least, get the instrument on trial until its quality can proven by use. Many ask as to size. A 3½″ or a 4″ is about as large as can be handled conveniently on a tripod if the instrument is moved about. A 5″ or even a 6″ may be used, but requires more than one to carry it about with safety. If one wishes a small observatory, then the size and equipment of an instrument is only limited by one's means. It might be added that the value of a small instrument is almost doubled by placing the same on a firm and permanent base.

I believe that I found Halley's comet on the night of Nov. 30th, and as the pains I have taken to confirm this only strengthens me in my convictions, I here suggest my method thinking it may aid another amateur. I found it in my 3½″ instrument. From the ephemeris given in the POPULAR ASTRONOMY, I estimated the location for Nov. 30th as near Aldebaran. The Moon was just barely out of the way, so I began the night before and spent two hours in carefully making four maps of the stars within or very nearly within the field of vision with my 45 power in use. This eyepiece takes in about 40 or 42 minutes of arc. My plan was to note the second evening (Nov. 30th) and see if there were any stars within this same field that I had not recorded on my maps. But the evening of November 30th was so much darker that there were a large number of additional stars there. So I carefully prepared four more maps (one each with Aldebaran to the north, south, east and west of the field of view). In all I had between sixty and seventy stars—most of them very faint—on my maps. Several evenings of careful study of these same fields of view with my maps have resulted in finding one dim star about 25′ from Aldebaran which was present on Nov. 30th, which was not there after that. It had no comet characteristics and appeared just like a very dim star. The same method may be employed as the comet comes near other stars. The evenings of Dec. 16, 21 and 31 are good times. A good star atlas will indicate the location for these evenings if the ephemeris is consulted.

Edgertown, Wis., Dec. 14, 1909. RUEL W. ROBERTS.

The Orbit of Σ 1768.—Mr. W. Doberck has recently (*A. N.* 4383) computed the following elements of the orbit of the double star Σ 1768:

$\varphi = 257°\ 33'$	$P = 553.6$ years
$\lambda = 36\ 39$	$T = 1859.15$
$y = 56\ 31$	$a = 2''.038$
$e = 0.9005$	Retrograde

A Brilliant Meteor was observed here this evening at $7^h\ 5^m\ 0^s$, C. S. T. It was first seen just above σ Cygni at a point, the position of which is approximately $\alpha = 21^h\ 20^m$, $\delta = +40°$. Its path was nearly parallel to the line joining α and ϵ Cygni, and it disappeared at the horizon at $\alpha = 21^h\ 30^m$, $\delta = +10°$. In brightness it far surpassed Venus, which had been shining in that part of the sky only a few minutes earlier. The head of the meteor was pear-shaped, the preceding part a brilliant yellow, the following part, the stem of the pear, a very deep red. The trail was not continuous, but was broken into approximately equal segments.

The flight of the meteor occupied about three seconds. The trail was visible for perhaps four or five seconds after the meteor had disappeared. The point of disappearance was near the position of Comet *a*, the head of which passed below the horizon only a few minutes before. The tail of the comet was still visible, and any one in this vicinity who was still watching the tail must have seen the meteor. It is hoped that other observations were obtained.

Yerkes Observatory, Feb. 3, 1910. FREDERICK SLOCUM.